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NOTICES

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VOL. 35, SEC. A AUGUST, 1953 NUMBER 2

STUDIES IN MONOZYGOTIC CATTLE TWINS

VII. THE RELATIVE IMPORTANCE OF INHERITANCE AND ENVIRONMENT IN THE PRODUCTION OF DAIRY CATTLE

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(Received for publication, 24 April 1953)

Summary

1. An experiment with monozygotic twins, designed to measure the effects of three levels of nutrition on milk, butterfat and casein production, is described. Only the aspects with a direct bearing on breeding problems are reported.

2. Estimates of the treatment differences (average for three seasons) were:

	Milk	Butterfat	Casein	B'fat (%)	Casein (%)
A—B	1365	76.1	37.0	.11	.07
B—C	716	42.2	18.3	.11	.03
A—C	2081	118.3	55.3	.22	.10

3. The following heritability coefficients were estimated: milk yield, .90; butterfat yield, .86; casein yield, .88; butterfat percentage, .95; and casein percentage, .94.

It is considered that these high values (compared with estimates from other sources) were due mainly to strict control over environmental factors not common to all members of the herd.

4. The following genetic correlations were estimated:

Milk x butterfat yield	.87
Milk x butterfat percentage	— .52
Milk x casein percentage	— .40
Butterfat yield x butterfat percentage	— .03
Butterfat percentage x casein percentage	.67

5. Problems of selection are briefly discussed in the light of these findings.

INTRODUCTION

The age-old question of the relative importance of inheritance and environment has a significant bearing upon feeding and breeding practices aiming at livestock improvement.

It is frequently maintained by breeders of dairy cattle and by scientists[1] that it is necessary to feed on a high level of nutrition, since otherwise the best cows are unable to show their producing capacity relative to poorer ones, and selection is therefore less accurate. Many pedigree breeders in New Zealand justify the practice of feeding concentrates to their cattle in a grassland environment on the basis of this claim, although it seems likely that the true reason lies in the advertising value of higher production records.

On the other hand, it can be argued that feeding on an abnormally high level may be disadvantageous, as it may lead to the selection of animals which do not thrive on normal or subnormal levels. In other words, if genotype-environment interactions are of importance, the optimum practice would be to select breeding stock in an environment similar to that in which they are going to perform.

The technical success of artificial insemination has largely changed the operational basis of dairy cattle improvement from the individual herd to the whole or large sections of the national cow population. As a consequence, it is now frequently necessary to compare the genetic worth of animals (individual performance as well as progeny or sib test) from records made in different environments. It is, therefore, important to know as precisely as possible to what extent environment may influence the accuracy of selection.

The relative importance of inheritance and environment on the expression of any characteristic is conveniently represented by the coefficient of heritability (h^2), defined as the proportion of the total variance directly due to genetic differences between individuals in a specified population. As a measure of the accuracy with which the genotype of an animal can be identified from its phenotype (for any characteristic), the value of h^2 plays an important part in predicting the merit of selection and breeding systems and the genetic progress expected. In addition, the absolute magnitude of the variation due to genetic differences between individuals is important in determining the "selection potential."

In the past, practically all investigations on the genotype-environment complex in dairy cattle have been based on data obtained from field surveys. This approach has been necessitated by the lack of suitable experimental material. Recently, however, the collection of reasonable numbers of monozygotic cattle twins, at Wiad in Sweden and Ruakura in New Zealand, has made possible a direct experimental approach to the problem. By virtue of their identical genotype, monozygotic twins are ideally suited for this type of investigation. In "split-twin" experiments, the genetic variation can be eliminated from treatment comparisons, while the environment can be varied at will. The analysis of a twin experiment allows a partitioning of the total variation into the parts ascribable to genotype, to environment (treatment), and to genotype-environment interaction + error respectively. The heritability coefficient derived from such an analysis differs from most previously calculated coefficients in that it relates to the total genetic variance, i.e. it includes all the epistatic and dominance, as well as additive gene effects. A comparison of the two heritability values should, therefore, provide an indication of the importance of gene-interactions as factors affecting productive ability.

At the present time in New Zealand it is customary to evaluate the merit of dairy cattle mainly on the basis of their ability to produce butterfat. Present industry marketing trends suggest it is likely that milk will have to be used for more comprehensive purposes than merely as a raw material in the manufacture of butter. In this event, greater attention must be given to the other solids of milk, such as, for instance, casein. When two or more characteristics are involved, greatest genetic progress is achieved when breeding animals are selected on the basis of a properly weighted selection index. Knowledge of genetic and phenotypic correlations between the characters selected for are prerequisites in the construction of such an index. Owing to the paucity of suitable data, very few attempts have been made in he past to estimate genetic correlations between various characteristics in dairy cattle.

In view of these considerations, it was decided in 1947 to use a number of monozygotic twin sets in an experiment to investigate as many as possible of the factors outlined above.

Three different levels of nutrition, typical of common farming practice in New Zealand, were chosen, to which the reaction of the twins could be measured. As dairy farming in this country is almost wholly pastoral, the rations were based mainly on growing grass and grassland products. This naturally involved free grazing experimental stock and created a situation where the animals within a treatment (in varying degree, depending on the severity of the treatment) determined their own nutritional levels. From a descriptive point of view, this certainly was a disadvantage, but it had the virtue of freeing the animals from the imposed restriction of theoretical or empirical feeding norms. The general plan of the experiment is similar to that used by Bonnier, Hansson and Skjervold[2] in their experiments with monozygotic twins.

Only the parts of the present work with direct bearings on breeding problems are discussed in the present communication. Nutritional aspects based on grazing behaviour studies, growth rates and on limited feed intake data will be presented in a later paper.

EXPERIMENTAL PROCEDURE

Methods and Material

The experiment involved three widely different feeding levels,

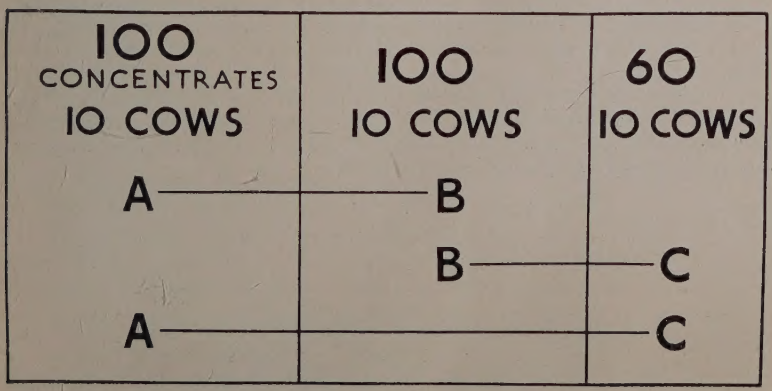

Fig. 1. Experimental design.

denoted A, B and C. Fifteen sets of monozygotic twins were divided into three groups of ten animals each in the following manner: five sets were split between A and B, five sets between B and C, and the remaining five sets between A and C. In design, this experiment was thus a balanced incomplete block (see Fig. 1). The experiment began in the Spring of 1947 and lasted for three consecutive milking seasons.

At the end of each of the first and second seasons, six sets of twins had to be replaced. The reasons for culling are shown in Table I. One of the sets which was excluded after the first season was re-introduced at the beginning of the third season.

TABLE I. REPLACEMENTS OF TWIN SETS

Comparison	No. of cows replaced	Reason
	At the beginning of the 1948-49 *season*	
A — B	T48 — T47	76 days between calving dates.
B — C	T14 — T13	52 days between calving dates.
	T63 — T64	72 days between calving dates.
A — C	T57 — T58	43 days between calving dates.
	T65 — T66	T65 failed to calve.
	T61 — T62	"under-shot" jaws (see text).
	At the beginning of the 1949-50 *season*	
A — B	T2 — T1	T2 failed to calve.
	T55 — T56	T56 developed Staphylococcal Mastitis early in the previous season.
B — C	T36 — T35	The udder of T36 broke down during the previous season. This set had, however, to be used (in the A—B comparison) as no other twins were available to replace T39—T40 (see below).
	T59 — T60	T60 aborted 2/3/49.
A — C	T53 — T54	151 days between calving dates.
	During the 1949-50 *season*	
A — B	T30 — T40	T39 developed Streptococcal Mastitis at calving.
A — C	T21 — T22	T22 developed virulent Staphylococcal Mastitis 30 days after calving.

NOTE.—The set T17—T18, which was placed in the A—B comparison during 1947-48, was changed to the A—C comparison at the beginning of the 1948-49 season, in order to yield the required age distribution.

The animals were not allocated to the groups strictly at random, as it was desirable to build up the numbers in each group at the same rate over the calving period. The three groups differed very little in mean calving dates, as can be seen in Table II.

TABLE II. MEAN CALVING DATES

Season	A	B	C
First	19/8	27/8	17/8
Second	2/8	6/8	7/8
Third	7/8	5/8	5/8

In the first season there were significant "between-set" differences in calving dates. The differences in the last two seasons were not significant.

The initial fifteen sets and the subsequent replacements during the last two seasons were introduced into the experiment immediately after calving. At this stage they were in good but not fat condition. The animals which remained in the trial for more than one season were subjected to the experimental treatments through the dry period. Strictly speaking, the treatments were therefore not comparable for all sets in the last two seasons. This, however, need not be considered a serious objection, as there was little evidence of carry-over effects in those animals remaining for more than one season. Table III shows the number of different sets used in each comparison and the number of years they remained in the trial.

TABLE III. NUMBER OF SETS USED AND DURATION IN EXPERIMENT

Years in Experiment	A—B	B—C	A—C	Total
1	6	6	4	16
2	3	3	4	10
3	1	1	1	3
Total	10	10	9	29

Finally, it must be noted that no culling on productive performance was attempted—in fact, the twin supply position was such that all the available twin material had to be used in each of the three seasons.

Treatments

A 26-acre block of permanent pasture land was divided into 14 even paddocks, each of which was subdivided into three sections in the proportions 10:10:6 (see Fig. 1). The average sizes of the three subdivisions were thus 0.71, 0.71 and 0.43 acres. The ten cows of the A group were allotted, on a daily-shift basis, one of the 0.71-acre sections out of each of the fourteen paddocks (a total area of 10 acres). Silage or hay was fed *ad lib.* when sufficient grass was not available during the dry summer period and during the winter months. In addition, the cows were given 1 lb. of a concentrate mixture (crushed oats or barley and extracted linseed meal in the proportions 4:1) for each 5 lb. of milk they produced, irrespective of the stage of lactation or the level of production.

The ten cows of the B group were pastured on the remaining fourteen 0.71-acre sections (a total area of 10 acres). Silage and hay were fed, as to the previous group. No concentrates, however, were fed.

Finally, the fourteen 0.43-acre sections (a total area of 6 acres) were allotted to the ten cows of the C group. They received only 60 per cent of the amount of silage and hay consumed by the B cows, with no concentrates.

All three groups were rotationally grazed according to common New Zealand practice, remaining only one day in each paddock. The choice of each daily paddock was governed by the requirements of the B group—the other two groups were moved simultaneously into their sections of the same paddock.

The treatments were intended to approximate three widely different levels of feed intake representative of the range of nutritional standards found on New Zealand dairy farms.

The A treatment represented the conditions on many pedigree cattle farms, where the main source of income depends on the sale of breeding stock. In order to achieve a higher "per cow" production, the cows on such farms are often forced, with the aid of concentrate feeding, to approach (within practical limits) the "ceiling" of their inherent capacity.

The B treatment typified good grassland farms on which the animals are maintained on a high, even level of nutrition based on ample pastures, supplemented in times of slow pasture growth by grassland products, hay and silage only. High per cow productions are aimed at also under these conditions in the belief that this will lead to the greatest net farming returns.

The C treatment was representative of a great many farms on which the cows, due to overstocking, are underfed at certain times of the year. This presumably leads to relatively low per-cow productions, but many farmers believe that, by virtue of the greater number of animals carried, the net return will be higher than obtained from cows managed in the manner of B treatment. From an experimental viewpoint, three levels of nutrition were thus involved: A—high; B—medium; C—poor.

Data collected and correction factors applied

Milk weights were recorded daily. Butterfat (Gerber) and casein (Walker[3]) contents were analysed daily on representative samples, except that a combined sample was taken for Saturdays and Sundays.

Lactation was terminated

(1) when the production fell below 8 lb. of butterfat for 28 days;

(2) six weeks prior to re-calving; or

(3) 309 days after calving (305-day lactation).

The records used in the following analysis represent the productions during a maximum lactation length of 305 days commencing from the fourth day after calving.

In view of the age differences existing among the experimental animals, it was necessary to convert the crude production figures to a maturity equivalent (ME) basis in order to avoid a possible overestimation of the "between-set" (hereditary) portion of the total variance. The butterfat (ME) records were calculated according to the method devised by the Herd Recording Council of the New Zealand Dairy Board. This consists of the addition of 70 lb. and 35 lb.

to the records of two- and three-year-old heifers respectively. The equivalent milk and casein yields were derived from the corrected butterfat yields.

The uncorrected figures for butterfat and casein percentages were used in the analysis of the data, as advancing age is known to cause only minor changes in these characteristics.

In each of the three seasons an abnormal lactation occurred which seemed to warrant adjustment. The reasons for using adjusted yields in these cases are set out below :

(1) The lactation of the cow T62 (Treatment C) in the year 1947-48 was very short, lasting only 107 days. Her production in the first 28 days period was as high as that of her co-twin T61 (Treatment A), but fell thereafter sharply, not only in relation to her twin but also in comparison with the other nine cows in her own group. This was undoubtedly due to her abnormally short lower jaw, which made her unable to gather enough grass (under the conditions of extreme close grazing in the C treatment) to sustain milk production even on a low level. Her co-twin T61 also had a shorter than normal lower jaw, but as the grass under the A treatment was fairly long at all times and she was fed on concentrates in addition to the pasture, her production did not suffer, in spite of her anatomical disability. Fig. 2 shows clearly the poor jaw development of this twin set.

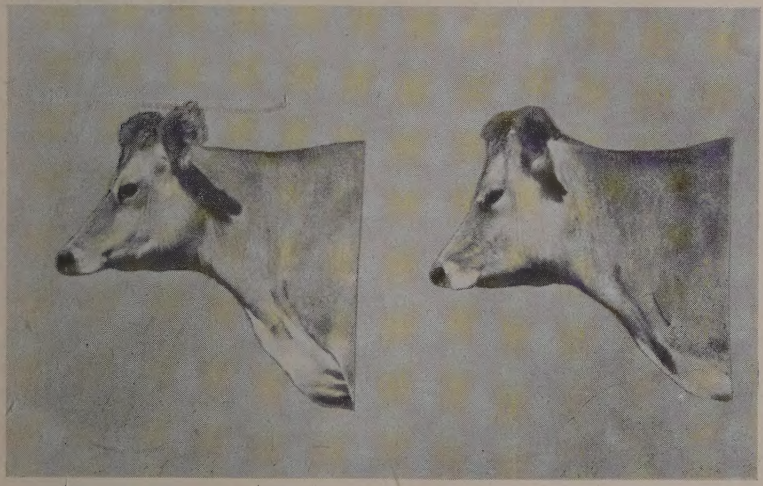

FIG. 2.—The twin set T61—T62, showing poor jaw development.

While the great difference of 251 lb. butterfat between the production of T61 and T62 is an excellent illustration of environment-inheritance interaction, it was the only case where such interaction could be demonstrated clearly, and it was thought that the inclusion of the record of T62 in the final analysis of the data in a small sample would have stressed unduly the general importance of this aspect. A value was therefore fitted by the method of least squares.

(2) In the very beginning of her lactation in the 1948-49 season, T56 (B treatment) suffered a total loss of one fore-quarter due to a staphylococcal infection following an injury. As no other sets were available for replacements, T56 had to remain in the experiment until the end of her lactation, her record being scaled up by one third. The performance of this set in the subsequent lactation (4), when treated alike, confirmed this as a reasonable approximation.

(3) One month after calving in the 1949-50 season, T22 (C treatment) developed staphylococcal mastitis in the right forequarter. The infection became generalized, with the result that her production suffered severely. Consequently the set T21—T22 was replaced by T129—T130, which, however, at that time were well into their lactation. Their production results could, therefore, not be used in the final analysis. Instead, it was decided to use the record of T21 (which, although milked outside the experiment, was treated as the cows of the B group) and includes an estimate of the production of T22 based on her first month's record.

RESULTS

The adjusted (ME) records for milk, butterfat and casein yields and for butterfat and casein percentages are shown in Tables IV—VIII.

1. *Treatment effects*: The three levels of nutrition induced wide differences in the milk, butterfat and casein yields. The maximum likelihood estimates of the treatment differences, together with the mean productions, are shown in Table IX.

The addition of concentrates had a greater effect than the reduction in the size of grazing areas, although the latter became more important as the trial proceeded.

The influence of the treatments on the butterfat and casein percentages was much less marked. The difference in butterfat percentage between the two pasture groups (B and C) was approximately equal to the difference between groups A and B, indicating that concentrate feeding had approximately the same effect as the reduction of the grazing area. The main effect on casein percentage, on the other hand, was caused by the addition of concentrates to pasture feeding.

The relatively much greater influences of the three treatments on the total milk, butterfat and casein yields than on the milk composition is clearly reflected in Table X, showing proportionate effects.

While the C treatment, for instance, reduced the total yields of milk, butterfat and casein by approximately 30 per cent over the A treatment and 10 per cent over the B treatment, the butterfat and casein percentages fell only by 4—5 per cent and 1—2 per cent respectively.

TABLE IV. MILK PRODUCTION IN lb.
(Converted to M.E. basis)

1947-48					1948-49					1949-50				
Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.
T2-1	8780	6523		2257	T2-1	8915	8528		387	T36-35	5314	5359		—45
T17-18	9613	7700		1913	T6-5	7135	6004		1131	T6-5	8008	5581		2427
T48-47	9041	7326		1715	T39-40	9905	8774		1131	T63-64	9554	7459		2095
T49-50	6450	6167		283	T49-50	6043	5824		219	T49-50	7701	6005		1696
T55-56	10158	8305		1853	T55-56	13482	(11207)*		2275	T119-120	10371	9649		722
Av.	8808	7204		1604	Av.	9096	8067		1029	Av.	8190	6811		1379
T14-13		4731	4451	280	T21-22		8791	7893	898	T21-22		9349	(8329)*	1020
T36-35		5407	5239	168	T36-35		5818	5911	—93	T52-51		6636	6548	88
T37-38		8738	8309	429	T37-38		10206	8825	1381	T37-38		10004	8828	1176
T59-60		4778	4916	—138	T59-60		5033	4513	520	T131-132		9306	7064	2242
T63-64		8053	7136	917	T94-93		8583	8274	309	T94-93		8884	7763	1121
Av.		6341	6010	331	Av.		7686	7083	603	Av.		8835	7706	1129
T44-43	7332		4837	2495	T44-43	8764		6471	2293	T44-43	7824		4912	2912
T54-53	7676		5803	1873	T54-53	7468		6412	1056	T128-127	7950		6759	1191
T57-58	7783		6040	1743	T17-18	9031		6721	2310	T17-18	7958		5265	2693
T61-62	7670		(5747)*	1923	T41-42	10044		8349	1695	T41-42	10975		7331	3644
T65-66	6328		4776	1552	T78-77	7211		5647	1564	T78-77	8369		5689	2680
Av.	7358		5441	1917	Av.	8504		6720	1784	Av.	8615		5991	2624

* Amended record. See pp. 73-74.

TABLE V. BUTTERFAT PRODUCTIONS IN lb.
(Converted to M.E. basis)

1947-48					1948-49					1949-50				
Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.
T2-1	475	347		128	T2-1	485	452		33	T36-35	242	248		—6
T17-18	547	442		105	T6-5	396	329		67	T6-5	422	288		134
T48-47	509	389		120	T39-40	519	451		68	T63-64	408	305		103
T49-50	307	280		27	T49-50	284	272		12	T49-50	326	255		71
T55-56	451	348		103	T55-56	573	(492)*		81	T119-120	391	357		34
Av.	458	361		97	Av.	451	399		52	Av.	358	291		67
T14-13		247	235	12	T21-22		429	397	32	T21-22		416	(336)*	50
T36-35		292	263	29	T36-35		288	279	9	T52-51		347	348	—1
T37-38		450	398	52	T37-38		495	428	67	T37-38		472	414	58
T59-60		290	292	—2	T59-60		303	269	34	T131-132		402	308	94
T63-64		364	314	50	T94-93		424	393	31	T94-93		398	340	58
Av.		328	300	28	Av.		388	353	35	Av.		407	355	52
T44-43	382		238	144	T44-43	461		319	142	T44-43	399		231	168
T54-53	403		289	114	T54-53	410		336	74	T128-127	380		294	86
T57-58	344		273	71	T17-18	522		373	149	T17-18	413		266	147
T61-62	428		(313)*	115	T41-42	459		364	95	T41-42	490		287	203
T65-66	374		267	107	T78-77	406		323	83	T78-77	431		293	138
Av.	386		276	110	Av.	452		343	109	Av.	422		274	148

* Amended record. See pp. 73-74.

TABLE VI. CASEIN PRODUCTION IN lb.
(Converted to M.E. basis)

1947-48					1948-49					1949-50				
Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.
T2-1	191	142		49	T2-1	248	230		18	T36-35	127	117		10
T17-18	234	186		48	T6-5	173	139		34	T6-5	195	133		62
T48-47	207	164		43	T39-40	248	215		33	T63-64	209	158		51
T49-50	152	147		5	T49-50	144	127		17	T49-50	180	136		44
T55-56	206	169		37	T55-56	278	(229)*		49	T119-120	200	175		25
Av.	198	162		36	Av.	218	188		30	Av.	182	144		38
T14-13		93	87	6	T21-22		198	182	16	T21-22		206	(181)*	25
T36-35		118	114	4	T36-35		134	130	4	T52-51		157	150	7
T37-38		191	181	10	T37-38		235	207	28	T37-38		223	191	32
T59-60		116	119	—3	T59-60		120	103	17	T131-132		184	134	50
T63-64		172	151	21	T94-93		181	174	7	T94-93		183	161	22
Av.		138	130	8	Av.		173	159	14	Av.		190	163	27
T44-43	163		107	56	T44-43	204		140	64	T44-43	189		112	77
T54-53	177		132	45	T54-53	177		148	29	T128-127	172		132	40
T57-58	191		146	45	T17-18	227		162	65	T17-18	208		124	84
T61-62	195		(150)*	45	T41-42	225		164	61	T41-42	240		142	98
T65-66	153		117	36	T78-77	177		138	39	T78-77	208		139	69
Av.	175		130	45	Av.	202		150	52	Av.	203		130	73

* Amended record. See pp. 73-74.

TABLE VII. BUTTERFAT PERCENTAGE

1947-48					1948-49					1949-50				
Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.
T2-1	5.41	5.32		0.9	T2-1	5.44	5.30		.14	T36-35	4.55	4.63		—.08
T17-18	5.69	5.74		—.05	T6-5	5.55	5.48		.07	T6-5	5.27	5.16		.11
T48-47	5.63	5.31		.32	T39-40	5.24	5.14		.10	T63-64	4.27	4.09		.18
T49-50	4.76	4.54		.22	T49-50	4.70	4.67		.03	T49-50	4.24	4.25		—.01
T55-56	4.44	4.19		.25	T55-56	4.25	4.39		—.14	T119-120	3.77	3.70		.07
Av.	5.19	5.02		.17	Av.	5.04	5.00		.04	Av.	4.42	4.37		.05
T14-13		5.22	5.28	—.06	T21-22		4.88	5.03	—.15	T21-22		4.45	(4.39)*	.06
T36-35		5.40	5.02	.38	T36-35		4.95	4.72	.23	T52-51		5.23	5.31	—.08
T37-38		5.15	4.79	.36	T37-38		4.85	4.85	—	T37-38		4.72	4.69	.03
T59-60		6.07	5.94	.13	T59-60		6.02	5.96	.06	T131-132		4.32	4.36	—.04
T63-64		4.52	4.40	.12	T94-93		4.94	4.75	.19	T94-93		4.48	4.38	.10
Av.		5.27	5.08	.19	Av.		5.13	5.06	.07	Av.		4.64	4.63	.01
T44-43	5.21		4.92	.29	T44-43	5.26		4.93	.33	T44-43	5.10		4.71	.39
T54-53	5.25		4.98	.27	T54-53	5.49		5.24	.25	T128-127	4.78		4.35	.43
T57-58	4.42		4.52	—.10	T17-18	5.78		5.55	.23	T17-18	5.19		5.05	.14
T61-62	5.58		(5.30)*	.28	T41-42	4.57		4.36	.21	T41-42	4.46		3.91	.55
T65-66	5.91		5.59	.32	T78-77	5.63		5.72	—.09	T78-77	5.15		5.15	—
Av.	5.27		5.06	.21	Av.	5.35		5.16	.19	Av.	4.93		4.63	.30

* Amended record. See pp. 73-74.

TABLE VIII. CASEIN PERCENTAGE

1947-48					1948-49					1949-50				
Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.	Set No.	A	B	C	Diff.
T2-1	2.17	2.18		—.01	T2-1	2.78	2.69		.09	T36-35	2.38	2.19		.19
T17-18	2.43	2.42		.01	T6-5	2.42	2.32		.10	T6-5	2.43	2.39		.04
T48-47	2.29	2.24		.05	T39-40	2.50	2.45		.05	T63-64	2.19	2.12		.07
T49-50	2.36	2.39		—.03	T49-50	2.39	2.18		.21	T49-50	2.33	2.26		.07
T55-56	2.03	2.04		—.01	T55-56	2.06	2.04		.02	T119-120	1.93	1.81		.12
Av.	2.25	2.25		—	Av.	2.43	2.34		.09	Av.	2.25	2.15		.10
T14-13		1.97	1.96	.01	T21-22		2.25	2.30	—.05	T21-22		2.20	2.17	.03
T36-35		2.19	2.18	.01	T36-35		2.30	2.20	.10	T52-51		2.37	2.30	.07
T37-38		2.19	2.18	.01	T37-38		2.30	2.34	—.04	T37-38		2.23	2.16	.07
T59-60		2.42	2.43	—.01	T59-60		2.38	2.29	.09	T131-132		1.98	1.90	.08
T63-64		2.13	2.11	.02	T94-93		2.11	2.10	.01	T94-93		2.06	2.07	—.01
Av.		2.18	2.17	.01	Av.		2.27	2.25	.02	Av.		2.17	2.12	.05
T44-43	2.22		2.22	—	T44-43	2.33		2.17	.16	T44-43	2.41		2.28	.13
T54-53	2.30		2.27	.03	T54-53	2.37		2.31	.06	T128-127	2.16		1.95	.21
T57-58	2.45		2.41	.04	T17-18	2.51		2.41	.10	T17-18	2.61		2.36	.25
T61-62	2.54		2.52	.02	T41-42	2.24		1.97	.27	T41-42	2.18		1.93	.25
T65-66	2.42		2.45	—.03	T78-77	2.45		2.44	.01	T78-77	2.48		2.45	.03
Av.	2.38		2.37	.01	Av.	2.38		2.26	.12	Av.	2.36		2.19	.17

TABLE IX. ESTIMATES OF TREATMENT DIFFERENCES

Comparison	Season	Milk (lb.)	B'fat (lb.)	Casein (lb.)	B'fat %	Casein %
A — B	1st	1598	91.7	37.2	0.12	0
	2nd	1079	59.5	32.6	0.07	0.10
	3rd	1418	77.0	41.1	0.13	0.11
B — C	1st	325	23.3	8.4	0.14	0.01
	2nd	654	41.8	16.7	0.09	0.02
	3rd	1168	61.6	29.9	0.09	0.06
A — C	1st	1923	115.0	45.6	0.26	0.01
	2nd	1733	101.3	49.3	0.16	0.12
	3rd	2586	138.6	70.9	0.22	0.17
Mean* productions	1st	6860	351.7	155.7	5.15	2.27
	2nd	7859	397.7	181.9	5.12	2.32
	3rd	7692	351.4	168.9	4.60	2.21

* Per lactation.

TABLE X. THE RELATIVE INFLUENCE OF TREATMENTS (EXPRESSED AS % OF THE HIGHER YIELDING GROUPS)

	B/A	C/B	C/A
Milk	84.1	91.0	74.2
Butterfat	82.5	89.9	70.9
Casein	82.0	90.2	70.6
Butterfat %	98.2	98.2	95.5
Casein %	97.2	98.8	95.7

2. *Variability within treatments*: Considerable variability existed between the yields of cows within each treatment group, as could be expected in view of the heterogeneous experimental material used. Two questions of importance arise—

(1) Was the variability within the three treatment groups of the same magnitude?

(2) Did the treatments induce the same relative variability in all characters under investigation?

To answer these questions, the range, standard deviation (S.D.) and the coefficient of variation were computed separately for each characteristic and each treatment, with the following results:

TABLE XI. MILK YIELDS

Season	Range (lb.)			S.D. (lb.)			Coeff. of variation (%)		
	A	B	C	A	B	C	A	B	C
1st	3830	4007	3858	1282	1470	1201	15.9	21.7	21.0
2nd	7439	6174	4312	2093	2085	1390	23.8	26.5	20.1
3rd	5661	4423	3916	1590	1816	1288	18.9	23.2	18.8

In the first season the range in milk yields was similar within all treatments, but in the last two seasons it was greatest within the A and smallest within the C treatment.

The standard deviations tended to be greater within the B treatment in all three seasons than in either A or C, while the A treatment showed higher values than the C in the last two seasons.

The coefficients of variation were higher within the B than within the other two treatments.

TABLE XII. BUTTERFAT YIELDS

Season	Range (lb.)			S.D. (lb.)			Coeff. of variation (%)		
	A	B	C	A	B	C	A	B	C
1st	240	203	163	74.9	68.6	47.2	17.7	19.9	16.4
2nd	289	220	159	72.0	86.4	52.0	18.2	22.0	14.9
3rd	248	224	183	66.5	74.3	53.1	17.0	21.3	16.9

The ranges and standard deviation of butterfat yields increased consistently with increasing group productions. The coefficients of variation, however, were lower within the two extreme treatments (A and C) than within the B treatment.

The trend in all three statistics was similar to that occurring in butterfat yields.

TABLE XIII. CASEIN YIELDS

Season	Range (lb.)			S.D. (lb.)			Coeff. of variation (%)		
	A	B	C	A	B	C	A	B	C
1st	82	98	94	26.1	32.5	29.7	14.0	21.7	22.8
2nd	134	115	104	42.1	46.8	29.5	20.0	25.9	19.0
3rd	113	106	79	29.7	33.4	24.8	15.4	20.0	16.9

When milk, butterfat and casein yields are considered together, the following generalization seems justified: the ranges in yield within treatments tended to become progressively smaller with lowered planes of nutrition, but the standard deviations were materially affected only by the lowest plane. The relative variability showed no such orderly trend, in that the coefficients of variation were highest on the intermediate but of similar magnitude on the two extreme levels.

TABLE XIV. BUTTERFAT PERCENTAGES

Season	Range			S.D.			Coeff. of variation (%)		
	A	B	C	A	B	C	A	B	C
1st	1.25	1.88	1.54	0.53	0.58	0.47	10.1	11.2	9.3
2nd	1.53	1.63	1.60	0.51	0.46	0.50	9.8	9.0	9.8
3rd	1.50	1.60	1.40	0.50	0.46	0.44	10.7	10.3	9.4

TABLE XV. CASEIN PERCENTAGES

Season	Range			S.D.			Coeff. of variation		
	A	B	C	A	B	C	A	B	C
1st	0.51	0.45	0.68	0.15	0.16	0.18	6.5	7.0	7.8
2nd	0.72	0.65	0.58	0.19	0.18	0.14	7.8	8.0	6.4
3rd	0.68	0.47	0.55	0.20	0.18	0.19	8.5	8.2	8.9

It is evident that the treatments had only little effect on the variability of either butterfat or casein percentages.

The difference in variability in the three quantitative characters investigated (milk, butterfat and casein yields) was not important—the average coefficients of variability being 21.0, 18.2 and 19.5 per cent respectively. The variability within butterfat and casein percentages, however, was much smaller, viz. 10.0 and 7.7 per cent.

TABLE XVI. RANK CORRELATIONS BETWEEN TWINS

Season	Milk			Butterfat			Casein		
	A–B	B–C	A–C	A–B	B–C	A–C	A–B	B–C	A–C
1st	0.9	1.0	0.6	0.9	0.7	0.6	0.8	0.9	0.9
2nd	0.8	1.0	1.0	0.9	0.8	0.7	0.8	1.0	0.7
3rd	0.8	0.9	0.6	0.6	0.9	0.9	0.8	0.7	0.6

NOTE:—Due to the small number of sets (5) involved in each comparison in each year, only correlations higher than 0.6 are statistically significant.

3. *Ranking order*: From a breeding point of view it is important to discover whether it would be possible to distinguish between inherently high and low producing twins, irrespective of feeding level. To this end, rank correlations between members of twins "split" between different treatments were computed, with the following results:

In regard to total yields the rank correlations were reasonably high, even when the twins were "split" between treatments which caused big average differences in production, i.e. A—C and A—B.

TABLE XVII. RANK CORRELATIONS FOR BUTTERFAT AND CASEIN PERCENTAGES

Season	Butterfat %			Casein %		
	A–B	B–C	A–C	A–B	B–C	A–C
1st	0.9	0.9	1.0	1.0	1.0	0.9
2nd	1.0	0.1	0.9	1.0	0.4	0.9
3rd	0.9	1.0	0.9	0.9	0.9	0.8

The rank correlations for butterfat and casein percentages were very high, with one exception (the twin comparison B—C in the 1948-49 season), indicating that the relative merit of the animals was largely unaffected by the treatment.

4. *Analysis of variance*: Although it would have been desirable to obtain an overall picture for the three seasons, a pooled analysis will not be presented, for the following reasons:

(1) A certain number only of the twin sets were carried over in successive seasons.

(2) The age distribution varied from season to season. (The true correction factors for age cannot be assumed independent of genotype and season.)

(3) Under New Zealand conditions, considerable seasonal variations, with attendant interaction effects, were to be expected (cf. Tables IV–VIII).

For any year it is possible to obtain unbiassed estimates of the three contributions to the observed total variation, namely:

(1) Treatments (s_T^2)

(2) Twin sets (s_H^2), which measures the extent to which the twin sets differ from each other.

(3) Residual (s^2). This term includes: (a) errors of measurement; (b) errors due to uncontrollable environmental factors specific to individuals; and (c) the interaction between twin sets and treatments.

TABLE XVIII. ANALYSIS OF VARIANCE

Season	Source of Variation: Treatment df	Treatment ms	Twin Sets df	Twin Sets ms	Residual df	Residual ms	Components: s_T^2	s_H^2	s^2
a. Milk Yield (entries divided by 10^4)									
1st	2	795	14	312	12*	14	104 38.2%	154 56.5%	14 5.3%
2nd	2	574	14	667	13	20	74 17.2%	336 78.2%	20 4.5%
3rd	2	1257	14	446	13	37	163 39.5%	212 51.4%	37 9.1%
b. Butterfat Yield									
1st	2	27750	14	7642	12	491	3629 46.5%	3688 47.2%	491 6.3%
2nd	2	19448	14	10477	13	407	2539 31.1%	5222 63.9%	407 5.0%
3rd	2	36167	14	7273	13	988	4691 52.5%	3259 36.5%	988 11.0%
c. Casein Yield									
1st	2	4304	14	1525	12	77	563 40.6%	748 53.9%	77 5.5%
2nd	2	4707	14	3024	13	90	616 27.7%	1521 68.3%	90 4.0%
3rd	2	9513	14	1514	13	180	1244 58.8%	692 32.7%	180 8.5%

df = degrees of freedom

ms = mean squares

The results of the analysis of variance for milk, butterfat and casein yields are shown in Tables XVIII a, b and c. The residual components were small, especially in the first two seasons, when they accounted for approximately only one-twentieth of the total variance. In the last season the residual was about twice as great, mainly due to the fact that the members of two sets of twins (T35—T36 and T51—T52) were but slightly affected by the treatments (see Table IV). The small magnitude of these residual variances emphasized the suitability of monozygotic cattle twins as experimental material in trials of the present design. Details of this aspect will be discussed in a separate paper.

The relative effects of the treatments fluctuated from season to season. The fact that the treatment variances were greatest (both absolutely and relatively) in the last season can perhaps be ascribed to accumulated treatment effects on the pastures and on the twins which had been in the experiment for more than one season. Similar effects in the second season could well have been masked by the prevailing exceptionally favourable pasture growth conditions.

Variation between twin sets was much greater in the second than in the first and last seasons. This could be due partly to a more inherently variable sample of twin sets, and partly to the fact that (due to the favourable season) the twins which were capable of high yields were able to produce to the near limit of their capacity.

The analyses of variance for butterfat and casein percentages are shown in Table XIX a and b.

TABLE XIX. ANALYSIS OF VARIANCE

Season	Source of Variance						Components		
	Treatment		Twin Sets		Residual				
	df	ms	df	ms	df	ms	s_T^2	s_H^2	S^2
a. Butterfat Percentage (entries multiplied by 10^1)									
1st	2	1232	14	5218	12	157	142 4.9%	2618 89.7%	157 5.4%
2nd	2	480	14	4524	13	98	51 2.1%	2295 93.9%	98 4.0%
3rd	2	951	14	4101	13	137	109 4.7%	2055 89.3%	137 6.0%
b. Casein Percentage (entries multiplied by 10^4)									
1st	2	2	14	503	12	3	—	259 98.9%	3 1.1%
2nd	2	297	14	546	13	31	35 10.6%	267 80.1%	31 9.3%
3rd	2	524	14	665	13	22	67 15.9%	333 79.0%	22 5.1%

df = degrees of freedom

ms = mean square

The magnitude of the residual and treatment terms fluctuated from season to season. They were, however, relatively small, except for casein percentage in the last two seasons, when the treatments had a much greater effect than in the first season. The reason for this is obscure.

The effect of twin-set differences was fairly constant over all three seasons and was by far the most important source of variation.

In general, it appears that the treatments exerted relatively much greater effects on the total yields than on the qualitative characteristics of production. The residual accounted for approximately the same proportion of the total variance of all five characteristics.

Eliminating the variation directly ascribable to treatment differences, the proportion of the remaining variance due to set differences is indicated in Table XX.

TABLE XX. BETWEEN-SET VARIANCE AS PERCENTAGE OF TOTAL (excluding treatments)

Season	Milk	Butterfat	Casein	Butterfat %	Casein %
1st	91.5	88.2	90.7	94.3	98.9
2nd	94.5	92.8	94.4	95.9	89.6
3rd	85.0	76.7	79.3	93.7	93.9
Average	90.3	85.9	88.1	94.6	94.1

The values in this Table are, in fact, the estimates of the heritability coefficients from the present data.

5. *Correlations between various characteristics*: Correlations between the observed values of two characteristics in an individual may result from:

(1) the influence of common environmental factors;

(2) their genetic control by common or linked genes.

In predicting the extent to which one characteristic will vary when selection pressure is brought to bear on another, it is important to know the magnitude of the genetic correlation (as distinct from the phenotypic or total correlation) that exists between the two traits.

In the preceding section (Tables XVIII and XIX), estimates of the components of variance due to twin sets, treatments and residuals were abstracted. Unbiassed estimates of the co-variances were obtained in analogous manner. From the variance and co-variance components, estimates were obtained of the correlations between four variates: milk and butterfat yields, butterfat and casein percentages[5]. Owing to the non-independence of the seasons and the difference in age composition of the twins used in the three seasons, pooled correlations were not computed. The results are shown in Table XXI.

TABLE XXI. CORRELATIONS BETWEEN TRAITS

Type of Correlation:—	1. Genetic			2. Environmental (incl. treatments)			3. Total (Phenotypic)		
Season	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
M x B'fat	.85	.92	.84	.99	.98	.99	.91	.92	.92
M x B'fat %	—.43	—.62	—.52	.62	.46	.72	—.18	—.48	—.19
M x Casein %	—.24	—.34	—.61	.59	.58	.76	—.13	—.15	—.14
B'fat x B'fat %	.14	—.28	.03	.73	.62	.78	.26	—.13	.22
B'fat x Casein %	.44	.69	.89	.11	.71	.72	.42	.68	.85

In view of the relatively small number of observations and consequent large sampling errors, it is not surprising that the values obtained varied from season to season. The inter-seasonal variation in the genetic correlation coefficients could in part be due to differences in inheritance amongst the twin sets used in the three seasons. Over the three seasons they were of the same order as the values calculated by Laben *et al.*[6], namely, 0.87 for milk x butterfat, —0.52 for milk x butterfat test and —0.03 for butterfat x butterfat test.

As the residual variances (and co-variances) were relatively small, the environmental correlations (col. 2, Table XXI) stemmed mainly from the differences caused by the three treatments, and are, therefore, liable to large errors of estimation. The phenotypic correlations (col. 3) may be compared with overall correlations on a between-herd basis. Since the treatments affected all the productive characteristics in the same direction (i.e. all environmental correlations were positive) the phenotypic correlations were, in general, greater than the corresponding genetic correlations. The extent of the differences reflected the relative degree to which the treatments affected the various traits.

"Phenotypic" correlations were also computed after first eliminating the treatment components. These are essentially equivalent to total correlations on a within-herd basis. Owing to the small magnitude of the residual components (relative to those for twin sets), these did not differ appreciably from the genetic correlations (col. 1) and are not therefore listed.

DISCUSSION

It is commonly believed by breeders that differences in herd averages are reflections of differences in genetic merit. In New Zealand, this attitude has been strengthened by Ward's[7] statement that at least 30—40 per cent of the differences in production levels between groups of herds can be ascribed to the influence of heredity. However, from the present experiment it is obvious that the various feeding practices can alter markedly the phenotypic expression of milk, butterfat and casein production of groups of cows comprising genetically identical individuals. Experience indicates that much greater differences in feeding practice occur in the field than in this experiment. Other environmental factors (milking methods and calf rearing, for instance), which were kept stable in this experiment, must presumably also add to the variations occurring between herd averages. Thus it would be possible to explain most of the variations in average productions between herds as due to differences in environment. This experiment suggests that the estimates made by Bonnier[8] and Robertson[9]—that only 8 and 7 per cent respectively of the between-herd variations are due to genetic variations—are probably more nearly correct than that of Ward[7]. In a personal note, Ward stated that, although it was not clearly indicated, his estimate of the inherited part of the between-herd variations referred only to the differences between two large and representative groups of very low and very high producing herds.

The cause of between-herd differences has an important bearing on the technique of dairy sire selection when based on progeny or sib testing. Because herds in general are small, it is inevitable that various

progeny groups are tested under usually very dissimilar environments. If it is thought that genetic factors in the main determine the differences between groups, then absolute production levels should receive major emphasis. If, on the other hand, it is conceded that environmental factors cause most of the between-herd variations, the merit of a sire should be measured by the yield of his progeny group under standardised environmental conditions or in relation to the production level of the rest of the herd. Based on these considerations, Hancock[10] has criticised the past and present methods of sire selection in New Zealand.

The average maturity equivalent production of 421 lb. of butterfat of the cows of the A group was surprisingly high compared with the New Zealand average of approximately 300 lb. As the identical twins can be assumed to be a reasonably representative sample of the dairy cow population of the district, this discrepancy is presumably due to differences in feeding and management levels. The mean difference of 76 lb. of butterfat between the concentrate-fed group (A) and the group full-fed on pasture (B) indicates that New Zealand pastures and pasture products are inadequate to allow stock of present-day standard to express fully their inherent capacity to produce.

The relatively great effect of concentrate feeding makes it important to view with caution the absolute production levels achieved in herds where this type of feeding is practised. The small effect of the treatments on the butterfat and casein percentages suggests that the selection of animals possessing the desirable level of these traits can be reasonably effective on a between-herd basis without a previous correction for differences in environment.

The small magnitude of the residual variances (Tables XVII and XIX) shows that good control was achieved of extraneous environmental factors operating within treatment groups. As the residual variances also include the genotype-environment interactions, it can be concluded that these were relatively unimportant, amounting to no more than 5 to 10 per cent., depending on the season and characteristic under consideration, of the total variance. If it can be substantiated, this finding is of special importance, as it seems that animals selected as most suitable for a specific level of nutrition would maintain their superiority at other levels. This situation is also illustrated by the high rank correlations obtained between members of sets of twins. As, however, the genotype-environment interactions tended to become more important with increasing treatment differences, it seems unwise to attempt to select dairy cattle in good environmental conditions if they are to perform in much poorer conditions. The production performance of the twin set T61–T62 with "undershot" lower jaws is illuminating in this connexion.

In general these conclusions are in agreement with recently published results from mice breeding experiments involving selection for high weight on two planes of nutrition (Falconer and Latyszewski[11]).

The high rank correlations also indicate that the feeding of stud stock on an uneconomically high level of nutrition is not justified on the grounds that it otherwise would not be possible to discriminate between good and poor producers. However, a reasonable level of

nutrition must obviously be maintained in view of the fact that on the lowest level (C treatment) the range of individual yields tended to contract, making differentiation more difficult.

The heritability coefficients estimated from the data in this experiment were approximately 2 to 3 times higher than those generally quoted. The reasons for this are complicated and require elaboration, but the scope of the problem is so wide that only a brief outline can be attempted in this paper.

The heritability coefficient is a ratio in which the numerator represents essentially the genotypic variance and the denominator the total or phenotypic variance. Thus, the reason why the coefficients found in identical twin experiments ($h^2_T = 0.85$ for butterfat and 0.95 for butterfat percentage) are greater than those obtained by previous methods ($h^2 = 0.20 — 0.25$ for butterfat and 0.50 — 0.60 for butterfat percentage) is either that the numerator used was greater or the denominator smaller or both. It is to be expected that the numerator (genotypic variance) estimated from a twin experiment should be greater than that found by comparing the performance of related animals, for the reason that the former includes not only the effects of additive genes, but also those of gene interactions (dominance and epistasis) plus the permanent effects of a common maternal environment, while the latter, in general, represents only additive genetic variation. On the assumption that the denominator (the phenotypic variance) is the same, it thus appears that gene-interaction and common maternal environment could account for some of the difference between h^2_T and h^2. However, the repeatability coefficients between two or more records of the same cow, which measures the same complex as h^2_T, have generally been found to be of the relatively low order of 0.4 for butterfat yield. Before accepting this explanation, therefore, it is necessary to decide whether the denominators used in the derivation of the two co-efficients are likely to be of similar magnitude. Superficially these are similar, as they include the same terms: variance due to (1) additive gene effects; (2) gene interactions; (3) maternal environment; (4) interaction between heredity and environment; (5) imperfect measurements of yields; and finally (6) environment effects not common to all members of the population. The last term includes the variation induced by a number of possible factors of which the most important may be poor control of or correction for disease, milking methods, feed supply and age.

Irrespective of the method of derivation employed, it is not likely that the Terms 1 – 4 inclusive vary appreciably. The major part of the difference between h^2_T and h^2 must be sought in variations of the Terms 5 and 6. Variations due to errors in the measurement of yield are likely to be of greater importance in the computation of h^2, as the latter almost invariably is based on records computed from monthly milk weights and butterfat tests, while the records used to derive h^2_T were based on daily weights and tests. Nevertheless, the variations from this source cannot be very great, as indicated by the following example:

The milk, butterfat and butterfat test data obtained in the present experiment for the 1948-49 season were re-computed on the basis of milk weights and butterfat tests obtained on the 15th day of each calendar month. The heritability coefficients calculated from the two types of record are shown below :—

	Daily Record	Monthly Record	Difference
Milk	0.95	0.93	0.02
Butterfat	0.93	0.90	0.03
Butterfat (%)	0.96	0.85	0.11

It is obvious from the above comparison that the major part of the difference between h^2_T and h^2 for milk and butterfat yields cannot be accounted for by the method of measurement employed in the present experiment. The position in regard to the butterfat percentage was slightly different, in that a relatively greater difference was caused. Since the overall variability of butterfat percentages was small, the high h^2_T was essentially due to very small within-set differences. Under monthly testing, even the small errors to be expected in the values obtained for individual animals could cause relatively great increase in the non-inherited portion of the total variance, with a consequent decrease of the heritability coefficient. However, even in the case of butterfat percentage, the increased error caused by monthly compared with daily test cannot account for the whole of the observed difference between h^2_T and h^2.

It appears, therefore, that the higher heritability estimates from twin data are chiefly due to the elimination (on an experimental basis) of a large portion of the uncontrollable environmental variation existing in the field data from which heritability coefficients are usually derived.

It is of interest in this connection to compare the estimates obtained in the present study with those derivable from the recent published reports of the Danish Progeny Test Stations. These data represent production records by first calving heifers in sire progeny groups of approximately 17 animals each. The heifers are assembled at special Stations (1 – 7 groups per Station) where they remain for the whole of their first lactation. Everything possible is done to ensure that all animals are subject to the same environment in regard to nutrition and management. Milk and butterfat records are computed from twice-weekly weights and tests. The standard of environmental control and the accuracy of recording thus approach the conditions of the experiment described in the present paper. From the data given in the last two reports available [12, 13] the following estimates for h^2 were obtained [14]:

		(a) Eliminating Station differences	(b) Ignoring Station differences
Butterfat	1949-50	0.69	0.80
	1950-51	0.76	0.92
Butterfat %	1949-50	0.61	0.85
	1950-51	0.47	0.77

These values are of the same order of magnitude as the heritability coefficients derived from the twin data. It seems, therefore, that the great difference between h_T^2 and h^2 is mainly due to the differences in the degree of environmental control achieved in the two populations from which the parameters were derived. The most cautious conclusion that can be reached from present data is that gene interactions and prenatal environment are not likely to be important factors in causing variability in production. The validity of this conclusion is of fundamental importance to the problem of designing better breeding systems.

With the aid of genetic correlations it is possible to estimate the change which will take place in one characteristic if a correlated characteristic is changed by selection. In view of the relatively restricted material analysed, this has not been attempted here. However, as previous authors have used phenotypic correlations in order to predict the outcome of certain breeding procedures, it is important to indicate some of the dangers inherent in such a practice. Krizenecky[15], [16] considered that no fall in butterfat percentage would occur as a result of selecting on milk production alone, since the milk-x-butterfat test phenotypic correlation, although negative, was very low. In the present paper it has been shown, however, that the genetic correlation between these characteristics is quite high and negative. Selection on the basis of milk yield alone is therefore likely to lead to an appreciable decrease in butterfat percentage. Ward[17], on the other hand, stressed selection for high percentage as a means of obtaining increased butterfat yield, on the basis of a positive phenotypic relationship between butterfat yield and butterfat percentage. There is considerable danger in his viewpoint (as was pointed out by Ward himself) if it is interpreted as meaning that selection for butterfat percentage alone will increase butterfat yields or that breeding for increased buttterfat yields involves an increase in butterfat percentage. If the low genetic correlation between these characteristics found in the present work and also by Laben *et al.*[6] is valid, selection for high butterfat percentage would not lead automatically to higher total fat yields.

The high values obtained from the present data for the genetic correlation between butterfat percentage and casein percentage suggest that it would be very difficult to breed for these two characters independently—contrary to the conclusion reached by Larsson *et al.*[18]

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The author wishes to acknowledge his indebtedness to Messrs. B. Quigley and W. Ritchie, in whose care the experimental animals were; to Mrs. E. Clarke for the butterfat and casein tests; and to Miss J. Webster for the statistical computations. Thanks are recorded to Dr. A. H. Carter for statistical advice and valuable co-operation in the preparation of this manuscript. Finally, he is grateful to Dr. C. P. McMeekan for encouragement and helpful criticism.

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STUDIES IN MONOZYGOTIC CATTLE TWINS

VIII. PERFORMANCE OF IDENTICAL TWINS WHEN UNIFORMLY TREATED AFTER HAVING BEEN SUBJECTED TO DIFFERENT TREATMENTS IN THE PREVIOUS LACTATION

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(*Received for publication, 24 April 1953*)

Summary

1. A uniformity trial involving ten sets of twins is described. In the preceding lactation the twins had been subjected to diverging nutritional levels, which caused fairly large differences in butterfat productions and body weights.

2. The differences in body weights were largely made up during the dry period.

3. The previous treatment had no consistent effect on milk and butterfat production even during the first 50 days after calving, but over this period the butterfat percentages of the more poorly treated twins were significantly lower than those of their co-twins. Over a 200-day period no significant difference could be found in any of the three characteristics.

4. It is concluded that the recuperative power of dairy cows (of the age class involved in the present trial) is such that, given opportunity to regain lost body weight during the dry period, identical twins previously subjected to fairly diverging treatments can be employed in new experiments without undue risk of the introduction of systematic errors.

Introduction

Information of the uniformity of identical twins which have been subjected to diverging experimental treatments in a previous lactation is of obvious importance from the point of view of the economic use of twin material in experimental work. An analysis was therefore effected of the production records of a number of twin sets which had been used during the whole of preceding lactation in a trial involving widely different nutritional levels.

Experimental Procedure

The twin sets and the trial in which they were used have been described in a previous paper (Hancock, 1953). Three levels of feeding were involved: A (high), B (medium), and C (low). The best indication of the differential severity of the treatments is provided by the fact that the average within-set difference was 84 lb. butterfat in favour of the better treated twins (see Table I).

For various reasons (death, barrenness and mastitis) the performances of only ten of the original fifteen sets were available for comparison.

During the dry period following the termination of the experiment, all animals were treated uniformly. They were fed on a generous amount of grass silage and a daily ration of autumn-saved pasture, and on pasture alone once the spring flush provided sufficient, high-quality grass.

The differences in butterfat production in the previous trial, the number of days dry and the average liveweights during the last three weeks of the experiment and the first three weeks after calving are given in Table I.

TABLE I. BUTTERFAT PRODUCTION AND LIVEWEIGHTS IN PRECEDING LACTATION

Previous treatment	Cow Number	Number of Years in Previous Trial	No. days dry	Butterfat Yield (lb.) in previous lactation	Av. weight during last 3 weeks of previous lactation (lb.)	Av. weight during first 3 weeks of current lactation (lb.)
A	T6		45	385	825	768
B	T5	2	39	253	831	781
A	T36		65	242	1204	1070
B	T35	3	78	248	1060	983
A	T49		42	326	1382	1237
B	T50	3	96	255	1252	1211
A	T119		48	321	1020	988
B	T120	1	111	287	929	960
B	T37		27	472	948	862
C	T38	3	70	414	871	858
B	T94		88	363	842	788
C	T93	2	65	305	816	743
B	T131		85	332	678	798
C	T132	1	98	238	853	834
A	T44		75	399	1101	971
C	T43	3	60	231	816	909
A	T78		73	396	914	819
C	T77	2	59	258	838	841
A	T128		72	310	791	756
C	T127	1	95	224	659	719
	Av. of better treated twins:		62	355	971	906
	Av. of poorer treated twins:		77	271	893	884

The substantial difference of 175 lb. liveweight in favour of the more poorly treated twin of the set T131–T132 at the end of the previous trial is difficult to explain. However, during the dry period, T131 made a good recovery. Ignoring signs, the average weight difference of 144 lb. in the last three weeks of the previous experiment was reduced to 36 lb. for the three weeks following calving.

After calving the cows were managed as one herd. As no consistent differences due to previous treatment could be discerned, the present trial was terminated after 200 days of lactation.

The total milk and butterfat productions and fat percentages of each animal for the first 50 and first 200 days of lactation are given in Table II.

The average productions of the previously better and more poorly treated twins are shown in Table III.

TABLE II. MILK AND BUTTERFAT PRODUCTION IN CURRENT LACTATION

Comparison and Cow No.	0–50 days			0–200 days		
	Milk	B'fat	%	Milk	B'fat	%
A T36	2051	112	5.46	5505	264	4.80
B T35	1952	93	4.76	5332	240	4.50
A T49	1593	82	5.15	5986	258	4.31
B T50	1632	85	5.21	5322	227	4.27
A T119	2298	83	3.61	7659	254	3.31
B T120	2678	82	3.06	8269	259	3.13
A T6	1393	74	5.31	4898	236	4.82
B T5	1399	70	5.00	4737	228	4.81
B T37	2107	95	4.51	7137	311	4.36
C T38	2407	104	4.32	8042	348	4.33
B T94	1997	79	3.96	5977	238	3.98
C T93	1985	80	4.03	6447	258	4.00
B T131	1829	75	4.10	6160	243	3.94
C T132	1928	77	3.99	6186	248	4.02
A T44	1622	71	4.38	6035	253	4.19
C T43	1554	71	4.57	5624	241	4.29
A T78	1667	93	5.58	5709	289	5.06
C T77	1688	89	5.27	5699	292	5.12
A T128	1533	81	5.28	4941	232	4.70
C T127	1709	81	4.74	5840	256	4.38
H	1809	84.5	4.67	6001	257.8	4.30
L	1893	83.2	4.39	6150	259.7	4.22

TABLE III. AVERAGE PRODUCTIONS OF THE PREVIOUSLY BETTER AND MORE POORLY TREATED TWINS

	0–50 days			0–200 days		
	Milk (lb.)	B'fat (lb.)	B'fat (%)	Milk (lb.)	B'fat (lb.)	B'fat (%)
Better treated twins	1809	85	4.67	6001	258	4.30
More poorly treated twins	1893	83	4.39	6149	260	4.22
Difference	—84	+2	+0.28	—148	—2	+0.08

The lower butterfat percentage of the more poorly treated twins during the first fifty days was largely compensated for by a higher milk yield resulting in almost equal butterfat yields. Over a 200-day period the fat percentages evened out, giving the more poorly treated twins a slight advantage in butterfat yields. Analysis of variance

(Table IV) indicates that the previous treatment (better v. more poorly treated twins) had no significant influence on milk or butterfat yields over either 50 or 200 days of lactation. However, the butterfat percentages of the more poorly treated twins were significantly lower ($P = 0.03$) during the first 50 days. Over a 200-days lactation the difference was not significant.

TABLE IV. ANALYSIS OF VARIANCE: MILK, BUTTERFAT AND BUTTERFAT PERCENTAGE

Period	Characteristic	Between sets			Within sets	
		Mean squares* (ms)	Variance components (vc)	Variance components (%)	ms = vc**	(v %)
0–50 days	Milk	2288	1071	88	146	12
	B'fat	231.1	103.3	81	24.5	19
	B'fat %	0.91	0.43	91	0.04†	9
0–200 days	Milk	19436	8997	86	1443	14
	B'fat	1709.0	750.8	78	207.5	22
	B'fat %	0.54	0.27	96	0.01	4

* 9 d.f.
** 10 d.f.
† Based on 9 d.f. after elimination of significant "treatment" effects.

DISCUSSION AND CONCLUSIONS

This trial revealed a marked capacity of dairy cows to recover from unfavourable treatment lasting from one to three years.

The absence of discernible after-effects of previous treatments indicates clearly that identical twins can be used with some confidence in further trials which involve milk and butterfat production, providing the feed level during the dry period preceding the new trial is sufficiently high to permit the previously more poorly treated twins to approach the bodyweights of their co-twins. However, even when this condition is fulfilled, it seems that the previous treatment may exert a significant although transient effect on the butterfat percentages.

The statistical efficiency of experiments in which twins previously treated as described here are employed will be discussed in a further special paper.

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STUDIES IN MONOZYGOTIC CATTLE TWINS

IX. THE VALUE OF IDENTICAL TWINS IN SHORT-TERM TRIALS

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(*Received for publication, 25 May 1953*)

Summary

1. Two short term trials are described, in which identical twins were used as experimental material:

(a) A trial in which the effect on lactation of meal-feeding before calving was measured;

(b) A trial in which turnips and silage were compared as supplementary fodders in the declining stage of lactation.

2. Meal-feeding before calving, at the level of approximately 1 lb. meal a day per 100 lb. liveweight, increased milk and butterfat production over the three months following calving by 10 and 11 per cent without having an appreciable effect on bodyweights and butterfat percentage.

3. When turnips and silage were fed as a pasture supplement on the basis of equal amounts of dry matter at a level of approximately half normal total dry-matter intake, it was shown that the turnip-fed cows produced approximately 9 per cent more milk and butterfat over an eight-week period of feeding. Bodyweights and butterfat percentage were not affected.

4. The usefulness of identical twins in experiments of this type is briefly indicated.

Introduction

In a previous paper[1], an example was given of the use of monozygotic twins in a trial lasting over a whole lactation. In the present communication, two experiments are described which illustrate the use of twins in short-term trials. The two periods chosen were:

(1) immediately before and after calving;

(2) the declining phase of lactation.

These are important in New Zealand's grassland economy because they are periods when cattle usually are subjected to nutritional stress.

TRIAL I: MEAL-FEEDING BEFORE CALVING

The feeding to dairy cattle of supplementary fodder in the form of concentrates is in general practised in New Zealand by stud-stock breeders only, who can recoup the cost through the enhanced value of stock. In a previous paper[1], it has been shown that the feeding of concentrates to dairy cows during the lactation may increase quite markedly the total butterfat produced, even under good pastural conditions. In dairy-cattle selection work in this country, therefore, it may be necessary to amend records achieved under concentrate feeding during lactation to make them comparable with those of cows fed on pasture alone.

In the above-mentioned trial, no concentrates were fed during the period between drying-off and calving. As it has been repeatedly claimed in the British popular farming press that this

practice causes marked increase in production, it was decided to use a number of identical twin sets to obtain a measure of the effects of this type of feeding.

EXPERIMENTAL PROCEDURE

Material and Methods: Eight sets of monozygotic twins (one set of three-year-olds (T133, T134) and seven sets of two-year-olds) were split into two groups in a restricted random manner to ensure a small difference in the average calving date. One month before their estimated calving dates, the cows of one group ("meal-fed") were given a concentrate mixture (crushed barley and linseed cake meal in the proportions 4 to 1) at the rate of 1 per cent of bodyweight per day. Chemical analysis of the mixture gave the following results:

Ash	Protein	EE	CF	NFE
3.6%	19.2%	1.7%	4.6%	70.9%

The control group received no concentrates before calving. The cows of both groups were pastured together throughout the trial. Before calving, they were given 30–40 lb. of grass silage per cow per day in addition to a ration of good autumn-saved pasture. At calving, all cows were in good but not over-fat condition.

The date of calving, number of days of meal feeding and the amount of meal consumed are shown in Table I.

TABLE I. CALVING DATES AND MEAL CONSUMPTION

MEAL-FED				CONTROL	
Cow No.	Calving date	Meal consumed (lb.)	Days of meal feeding	Cow No.	Calving date
T134	24 July	207	31	T133	8 July
T167	27 July	168	31	T168	4 Aug.
T174	12 Aug.	206	32	T173	22 July
T185	18 Aug.	161	35	T186	20 Aug.
T190	3 Aug.	106	30	T189	27 July
T196	12 Aug.	120	29	T195	15 Sept.
T205	26 July	136	34	T206	2 Aug.
717	25 July	147	29	718	28 July
Mean	3 Aug.	156	31	Mean	4 Aug.

As some of the advantages of "steaming-up" may depend on the ability of the cows so treated to ingest and utilize greater quantities of nutrients after calving (if these are offered in an easily available form), the following feeding regime was adopted:

During the first month after calving, both groups of cows were given concentrates at the rate of 1 lb. for every 5 lb. of milk produced, and at half of this rate during the second month. They were rationed on an excellent autumn-saved pasture and given silage *ad lib.* until sufficient spring grass was available to feed them on pasture alone.

Milk weights were recorded daily from the fourth day after calving. Butterfat content (Gerber) was determined daily on representative samples, except on Saturday and Sunday, when a combined sample was taken. The animals were weighed once a week.

RESULTS

(1) *Up to calving*

(a) *Udder congestion*: As excessive feeding before calving is said to cause udder congestion, it was decided to make a comparison of the relative severity of this condition shown by the animals of the two groups. An attempt to measure the pressure with a tympanometer proved a failure, due to the imperfect elasticity of the udder tissue. However, only small differences could be detected on visual comparison (see Fig. 1). In no case was the congestion sufficiently great to cause discomfort.

(b) *Bodyweight*: The average differences in bodyweight (see below) for the four weeks before calving were small and not significant:—

Group	Weights in lb. at week before calving indicated			
	4th	3rd	2nd	1st
Meal-fed	768	781	792	811
Control	769	776	779	805
Differences	—1	+5	+13	+6

TABLE II. BIRTH WEIGHT AND SEX OF CALVES AND LENGTH OF PREGNANCY

MEAL-FED				CONTROL			
Cow No.	Pregnancy (days)	Calf Weight (lb.)	Calf Sex	Cow No.	Pregnancy (days)	Calf Weight (lb.)	Calf Sex
T134	279	61	F	T133	280	53	F
T167	283	64	F	T168	283	55	M
T174	283	50	M	T173	285	41	F
T185	289	68	M	T186	?	65	M
T190	283	58	M	T189	284	51	M
T196	281	56	F	T195	?	?	F
T205	283	58	F	T206	284	48	F
717	280	55	M	718	287	62	M
Mean	282*	59.1*		Mean	284	53.6*	

* These averages exclude values for T196.

FIG. 1(a and b).—Four sets of a twin showing degree of udder congestion immediately after calving. (Top twin meal-fed in each case.)

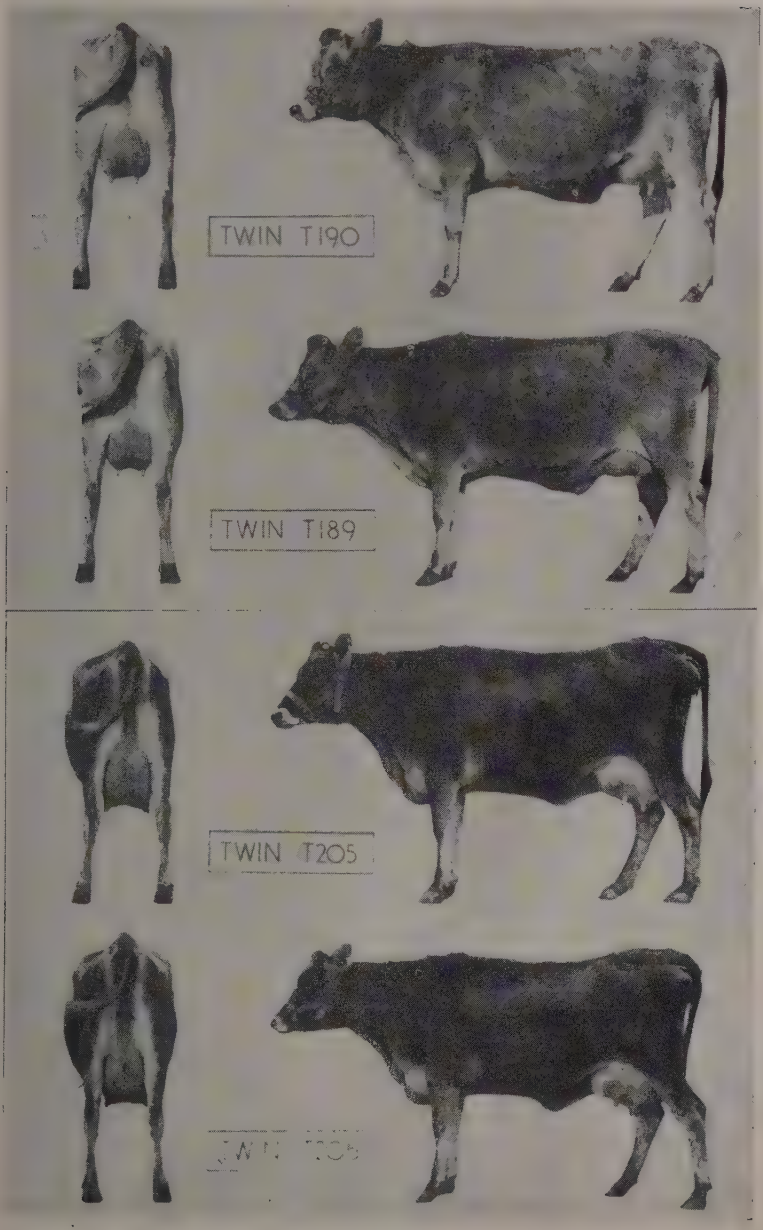

FIG. 1 (b).

The slightly greater gain in bodyweight before calving of the meal-fed cows may have been due to greater foetal growth. Table II shows the birth weights and sex of the calves and the length of pregnancy.

The same number of bull and heifer calves were born within each group. The calves of the meal-fed twins were heavier than their co-twins in six of the seven cases where weights of both calves were known. In the seventh case the period of pregnancy of the control twin (718) was seven days longer than that of her meal-fed co-twin (717), which may have accounted for the greater birth-weight of the calf of 718. Nevertheless, the observed average difference was significant ($p = 0.05$).

(c) *Calving dates*: Cow T174 developed mastitis seven weeks after calving and was, therefore, together with her twin T173, excluded from the following discussion. The mean calving date for the remaining meal-fed animals was 4½ days later than for their mates. The analysis of variance in Table III indicates that neither this difference nor the variation between sets was significant. It is hardly likely, therefore, that the group differences in calving dates could have affected materially the treatment comparisons made in the discussion.

TABLE III. ANALYSIS OF VARIANCE: CALVING DATES

(Excluding T173—T174)

Source of variation	df	ss	ms	Significance
Treatments	1	69	69	NS
Twin sets	6	2699	450	NS
Residual	6	725	121	
Total	13	3492		

(2) *After calving*

Systematic differences in production between the two groups became negligible approximately three months after calving. Mean growth and lactation curves for the first three months are shown in Fig. 2.

Initial inspection of the data indicated marked heterogeneity in the lactation curves of the animals. The production data were, therefore, analysed on the basis of three 4-weekly periods post-calving. Table IV shows the milk and butterfat yields and the butterfat percentages of all the experimental animals. The corresponding analysis of variance is presented in Table V. The inconsistency of the lactation curves of the different twin sets is reflected in the significant twin-set x period interaction for all characters.

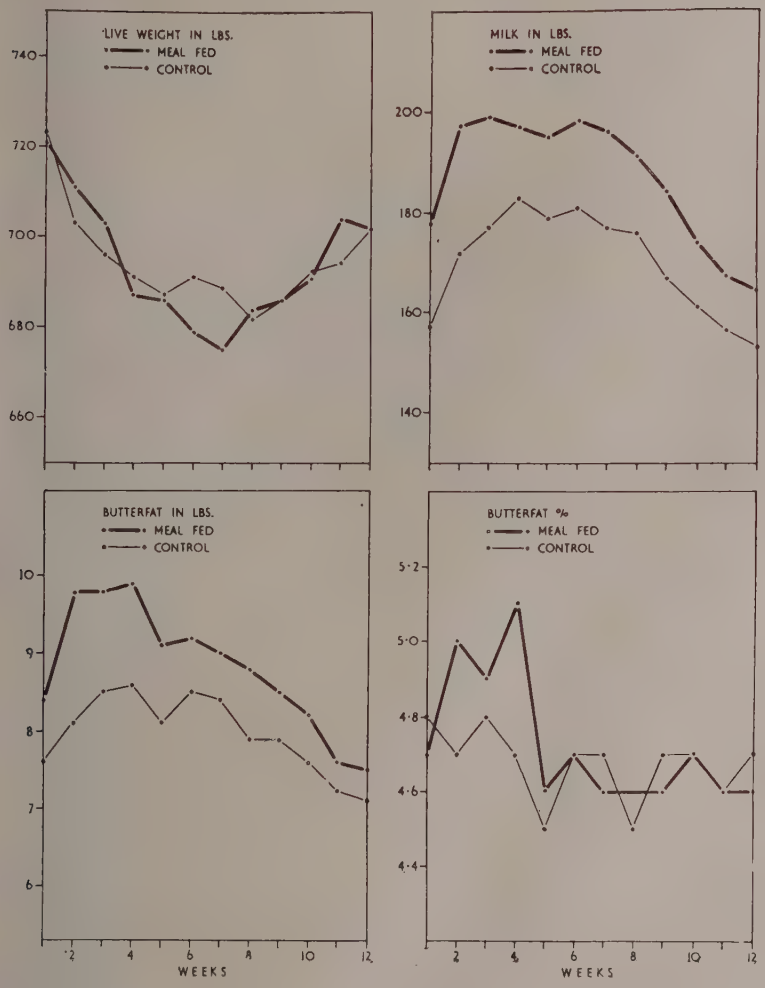

FIG. 2.—Mean growth and production curves.

(a) Liveweights: The average bodyweights (lb.) in the first and last weeks of each of the three 4-weekly periods following calving are shown below:

Group	Period I		Period II		Period III	
	1st week	4th week	1st week	4th week	1st week	4th week
Meal-fed	721	687	686	684	686	702
Control	723	691	687	682	686	702
Differences	—2	—4	—1	2	0	0

It is clear from the above comparison and from the analysis of variance (Table V) that the overall treatment effect was at all times negligible. The only significant sources of variation were those associated with differences amongst twin sets—their main effects and their interactions with both treatments and periods.

TABLE IV. AVERAGE PRODUCTIONS PER WEEK OVER THREE 4-WEEK PERIODS

Group	Twin No.	Period I			Period II			Period III			I + II + III		
		M	F	%	M	F	%	M	F	%	M	F	%
M	T134	299	16.6	5.55	276	14.0	5.08	248	12.8	5.16	275	14.5	5.27
C	T133	241	14.1	5.85	238	13.3	5.59	195	10.5	5.40	225	12.6	5.63
M	T167	181	8.0	4.39	179	8.0	4.45	172	7.5	4.37	177	7.8	4.40
C	T168	169	7.4	4.34	175	8.1	4.62	150	7.4	4.91	165	7.6	4.62
M	T185	269	12.1	4.50	281	11.4	4.06	238	10.0	4.21	263	11.2	4.26
C	T186	229	9.9	4.33	268	10.6	3.96	246	10.7	4.33	248	10.4	4.19
M	T190	183	8.2	4.48	178	7.1	4.00	187	7.3	3.89	183	7.5	4.12
C	T189	180	7.9	4.40	172	6.6	3.85	177	7.1	4.00	176	7.2	4.09
M	T196	172	8.8	5.12	178	9.5	5.35	174	9.6	5.51	174	9.3	5.33
C	T195	180	8.7	4.83	188	9.3	4.97	162	8.2	5.08	176	8.7	4.96
M	T205	218	10.4	4.76	237	9.7	4.10	229	9.4	4.10	228	9.8	4.31
C	T206	211	8.8	4.16	229	9.2	4.04	218	9.1	4.15	219	9.0	4.11
M	717	95	5.0	5.26	109	5.6	5.13	26	1.4	5.29	76	4.0	5.20
C	718	42	2.0	4.73	37	1.9	5.07	6	0.3	5.22	28	1.4	4.91
Av.													
M		203	9.9	4.86	206	9.3	4.54	182	8.3	4.55	197	9.2	4.66
C		179	8.4	4.69	187	8.4	4.51	165	7.6	4.61	177	8.1	4.61

M = Milk yield; F = Butterfat yield; % = Butterfat test.

TABLE V. ANALYSIS OF VARIANCE: MILK, BUTTERFAT, BUTTERFAT PERCENTAGE AND LIVEWEIGHTS

Source of variation	d.f.	Milk[1]		Butterfat[1]		Butterfat %[2]		Liveweight[3]	
		m.s. (x 10^{-2})	v.c. %	m.s.	v.c. %	m.s. (x 10^{2})	v.c. %	m.s.	v.c. %
Treatments	1	666*	3.2	173*	3.5	2.1	—	10	—
Twin sets	6	4,563**	86.6	1,082**	85.4	175.5**	76.5	39.100**	89.0
Periods	2	311*	2.1	88*	2.2	10.6	—	1,437	0.8
Tr. x Sets	6	103**	3.2	19	2.0	9.6**	7.6	1,154**	4.8
Tr. x Periods	2	6	—	10	0.2	7.3*	2.3	73	—
Sets x Periods	12	63*	2.5	21*	3.6	7.8**	8.8	616*	3.3
Tr. x Sets x Periods	12	21	2.4	6	3.1	1.7	4.8	160	2.1

[1] 4-weekly totals
[2] 4-weekly means
[3] Means of 4 consecutive weekly weights
* Significant at 5%
** Significant at 1%

The significant set x period interaction suggests different growth patterns among the various sets. Table VI shows that increase or decrease in liveweights was fairly consistent for members of all twin sets, except T189—T190. It is not possible to explain satisfactorily the between-set differences in liveweight changes on the basis of age, initial weight, or level of butterfat production.

TABLE VI. LIVEWEIGHTS OF INDIVIDUAL ANIMALS
(Expressed in lb.)

Twin No.	Treatment	Period I	Period II	Period III	Increase or decrease
T134	M	813	758	768	—45
T133	C	845	817	781	—64
T167	M	752	706	700	—52
T168	C	774	735	745	—29
T185	M	754	764	769	+15
T186	C	744	761	793	+49
T190	M	669	652	684	+15
T189	C	650	618	611	—39
T196	M	578	553	576	—2
T195	C	572	567	572	0
T205	M	663	630	642	—21
T206	C	638	611	613	—25
717	M	710	704	733	+23
718	C	700	703	748	+48
Mean	M	706	681	696	—10
	C	703	687	695	—8

(b) Productions: The absolute and relative treatment differences in milk and butterfat yield (lb. per cow per week) and butterfat tests are shown in Table VII.

TABLE VII. ABSOLUTE AND RELATIVE TREATMENT DIFFERENCES IN MILK AND BUTTERFAT YIELDS

	Period I	Period II	Period III	Total
Milk (lb.)				
(absolute difference)	24	19	17	20
(% difference)	11.7	9.1	9.5	10.1
Butterfat (lb.)				
(absolute difference)	1.5	.9	.7	1.1
(% difference)	15.0	9.7	8.2	11.0
Butterfat (%)				
(absolute difference)	.17	.03	—.06	.05
(% difference)	3.5	.7	—1.3	1.1

Although the differences in milk and butterfat yield were only of the order of 10 and 11 per cent, they were significant (Table V).

The significant treatment x set interaction for milk yield was partly due to the anomalous reaction of the set T195—T196. From Table IV it can be noted that T195 (control) produced more milk than her meal-fed twin, possibly due to the fact that, being a late calver, she was older, and subjected to different pasture conditions, at the beginning of lactation. There was a general tendency for the treatment differences to become smaller with advancing lactation, but this was not significant.

The analysis of variance for butterfat yield followed in general the same pattern as that for milk yield, except that the treatment x set interaction was not significant. Although the various twins did show differences in their reaction to the treatments, there was in all cases an increase in butterfat production due to meal-feeding before calving.

The overall treatment difference in butterfat test was negligible, but (as Table IV shows) at the beginning there was a tendency for the meal-fed twins to produce milk of higher test than their mates, and this resulted in a significant treatment x period interaction. The highly significant set x treatment interaction is a measure of the inconsistency among the twin sets in their reaction to the treatments as regards butterfat test.

DISCUSSION AND CONCLUSIONS

This trial has shown the possibility of increasing the production of milk and butterfat in the initial stages of lactation by the feeding of meal over a period of one month before calving, providing the cows are well-fed after calving. As body-weights were unaffected by this treatment, it can be concluded that the increase in production was not primarily due to the ability of the meal-fed cows to draw to a greater extent nutrients for milk production from body reserves.

The value of identical twins in an experiment such as this can be gauged from the great importance of the between-set variances (see Table IV). While the significant treatment differences accounted for only 3.2 and 3.5 per cent of the total variance in milk and butterfat yields, 86.6 and 85.4 per cent could be ascribed to differences between twin sets. For butterfat percentage and liveweight the between-set variances were of a similarly high order.

The treatment x set variance must be considered in part a function of true genotype-environment interaction and in part the result of effects of previous (or extra-experimental) environmental factors.

The significant set x period interaction reflects mainly inherent differences amongst the sets in production and weight changes with time.

TRIAL II. TURNIPS VERSUS SILAGE AS SUPPLEMENTARY FODDER IN THE DECLINING PHASE OF LACTATION

INTRODUCTION

The most difficult period of the year in which to provide high quality grass for dairy cows in New Zealand is the summer, when low rainfall during the time between mid-January and mid-March generally causes a marked slowing down of growth and a deterioration of the quality. Grass silage is the most commonly used supplementary fodder, but in general the quality is such that it is not considered a milk-promoting forage. Because of the labour involved and the difficulty of re-establishing ploughed pastures, there is amongst dairy farmers a decided reluctance to grow summer crops such as kale, chou moellier or soft turnips. However, of late years, new strains of grasses and clovers have been bred which are so much better than the previous strains that grassland research workers strongly recommend farmers to plough and reseed old pastures. If this is to become common practice, it is likely that a crop such as soft turnips may become important in the nutrition of dairy cows. The short period this crop occupies the land fits admirably into a system of spring ploughing of the old pastures with reseeding in the early autumn. This paper describes a trial in which turnips are compared with silage as a milk-producing feed.

EXPERIMENTAL PROCEDURE

(1) *Material*: Nine sets of identical twins were split between two groups in such a manner that the difference in the average butterfat

TABLE VIII. AGE OF THE EXPERIMENTAL ANIMALS, DAYS SINCE PREVIOUS CALVING AND DAYS PRIOR TO NEXT CALVING

TURNIP GROUP				SILAGE GROUP		
Twin No.	Age (yr.)	Days from calving	Days to calving	Twin No.	Days from calving	Days to calving
T 94	4½	126	259	T 93	145	186
T129	3½	159	197	T130	139	empty
T132	3½	136	208	T131	156	187
T135	3½	158	201	T136	131	empty
T186	2½	150	205	T185	152	191
T190	2½	166	177	T189	174	171
T195	2½	124	209	T196	158	193
T206	2½	168	216	T205	175	206
T211	2½	170	196	T212	176	197
Av.		151	208		156	190*

*Excluding T130 and T136

production for the three weeks prior to the beginning of the experiment was small. Table VIII shows the ages of the experimental animals, the number of days elapsed since calving and the number of days before next calving.

Milk weights were recorded daily. Butterfat contents (Gerber) were analysed daily on representative samples, except that a combined sample was taken for Saturdays and Sundays.

(2) *Feeding*: The trial began on 17 January, 1951, and lasted for eight weeks.

Each of nine paddocks (a total area of 17 acres) of good pasture land was divided into two equal parts. One half was allotted to the turnip and the other half to the silage group. Both groups were rotationally grazed, moving daily into a new paddock.

The pasture growth during the first four weeks of the trial was relatively good, but slowed down appreciably towards the end of the trial, owing to lack of rain.

The silage had been made in stack, of pasture grass (mainly perennial ryegrass and white clover) in the early flowering stage. No chemical analysis was made of the silage, but it was considered to be of average New Zealand standard—rather fibrous but sweet and quite palatable. The turnips were of the variety "Green Globe", drill-sown at the beginning of November and hand-thinned and inter-row cultivated once.

It was attempted to feed the silage and turnips at the level of approximately half normal dry-matter intake. This was achieved by giving the two groups, each of nine cows, 550–600 lb. of silage and 1,000 lb. turnips respectively per day in two feeds. The fodders were spread on the grass, according to usual New Zealand practice.

Dry matter determinations were made once a week. The following quantities (lb.) were offered to the cows over the 8-week period:—

	Total	Average dry matter (%)	Total dry matter	Dry matter per cow per day
Silage	32,445	16.02	5,198	10.3
Turnips	57,065	9.06	5,170	10.3

The refusals of both fodders were very small.

In general, it was noted that, in comparison with silage, the turnips had a laxative effect. This did not seem to have an adverse effect on the health of the cows, except in the case of T93, which scoured very badly and had a relatively low production. Her production record, however, was not excluded from the analysis, as it is likely that the turnip diet was directly responsible for her digestive upset.

After the end of the experimental period, the two groups were pastured together and given as supplementary feeding approximately 30 lb. of turnips and an equal amount of silage per day and per cow for the first two weeks, and 50 lb. of silage in the third week.

RESULTS

The group means of liveweight, milk and butterfat yield and butterfat percentage in the three weeks before the experiment, during

TABLE IX. AVERAGE BODYWEIGHTS AND PRODUCTIONS

Character	Group	Weeks before experiment			Weeks of experiment								Weeks after experiment		
		3	2	1	1	2	3	4	5	6	7	8	1	2	3
Body-weights (lbs.)	T	764	780	764	757	762	742	722	729	760	759	761	768	784	796
	S	733	759	750	752	748	743	742	758	756	749	766	742	742	752
	Diff.	31	21	14	5	14	—1	—20	—29	4	10	—5	26	42	43
Milk (lb.)	T	165	157	158	153	150	152	144	129	123	114	106	95	84	74
	S	165	159	158	148	137	144	139	120	113	98	90	91	90	85
	Diff.	0	2	0	5	13	8	5	9	10	16	16	4	—6	—11
Butterfat (lb.)	T	7.48	6.75	6.48	6.66	6.29	6.68	6.47	5.82	5.78	5.12	5.04	4.73	4.18	4.05
	S	7.33	6.71	6.60	6.32	5.98	6.36	6.13	5.23	5.18	4.37	4.18	4.19	4.27	4.32
	Diff.	.15	.04	—.12	.34	.31	.32	.34	.49	.60	.75	.86	.54	—.09	—.27
Butterfat (%)	T	4.54	4.31	4.10	4.34	4.21	4.41	4.49	4.53	4.68	4.48	4.77	4.99	5.00	5.46
	S	4.44	4.23	4.16	4.28	4.36	4.42	4.40	4.37	4.61	4.48	4.64	4.58	4.73	5.09
	Diff.	.10	.08	—.06	.06	—.15	—.01	.09	.16	.07	0	.13	.41	.27	.37

TABLE X. AVERAGE WEEKLY BODYWEIGHTS AND PRODUCTIONS FOR INDIVIDUAL TWINS

Character	Period	Group	T94 –93	T129 –130	T132 –131	T135 –136	T186 –185	T190 –189	T195 –196	T206 –205	T211 –212
Bodyweights (lb.)	3 weeks before expt.	T	819	806	957	943	809	730	575	645	637
		S	809	748	888	930	812	687	575	673	605
		Diff.	10	58	69	13	—3	43	0	—28	32
	8 weeks expt.	T	753	780	938	923	782	712	562	634	658
		S	820	749	877	917	809	712	593	692	597
		Diff.	—67	31	61	6	—27	0	—31	—58	61
	3 weeks after expt.	T	775	819	970	985	817	746	593	676	661
		S	795	737	842	884	804	732	575	703	634
		Diff.	—20	82	128	101	13	14	18	—27	27
Milk (lb.)	3 weeks before expt.	T	203	127	195	199	182	117	128	137	151
		S	211	119	187	223	185	110	121	137	167
		Diff.	—8	8	8	—24	—3	7	7	0	—16
	8 weeks expt.	T	151	108	161	164	160	81	114	124	141
		S	158	108	140	181	139	51	98	104	132
		Diff.	—7	0	21	—17	21	30	16	20	9
	3 weeks after expt.	T	84	55	122	107	118	16	74	81	107
		S	116	78	108	148	99	0	63	75	112
		Diff.	—32	—23	14	—41	19	16	11	6	—5
Butterfat (lb.)	3 weeks before expt.	T	8.30	5.76	7.47	6.68	8.44	4.50	6.88	6.08	8.01
		S	8.07	5.10	7.55	7.39	8.24	4.13	6.89	5.71	8.83
		Diff.	.23	.66	—.08	—.71	.20	.37	—.01	.37	—.82
	8 weeks expt.	T	6.20	4.99	6.75	5.81	7.51	3.54	6.19	5.25	7.48
		S	6.60	4.98	5.80	6.08	6.70	2.29	5.48	4.61	6.69
		Diff.	—.40	.01	.95	—.27	.71	1.25	.71	.64	.79
	3 weeks after expt.	T	3.77	3.03	6.06	3.98	6.16	0.74	4.88	3.94	6.32
		S	5.60	3.62	4.93	5.33	5.30	—	4.40	3.52	5.93
		Diff.	—1.83	—.59	1.13	—1.35	.76	.74	.48	.42	.39
Butterfat (%)	3 weeks before expt.	T	4.09	4.54	3.82	3.36	4.64	3.83	5.37	4.45	5.31
		S	3.84	4.28	4.06	3.32	4.45	4.15	5.68	4.19	5.29
		Diff.	.25	.26	—.24	.04	.19	—.32	—.31	.26	.02
	8 weeks expt.	T	4.11	4.62	4.19	3.54	4.69	4.37	5.43	4.23	5.30
		S	4.18	4.61	4.14	3.35	4.82	4.49	5.59	4.43	5.07
		Diff.	—.07	.01	.05	.19	—.13	—.12	—.16	—.20	.23
	3 weeks after expt.	T	4.51	5.52	4.98	3.72	5.51	4.53	6.65	4.86	5.89
		S	4.55	4.66	4.53	3.60	5.38	—	5.93	4.69	5.38
		Diff.	—.04	.86	.43	.12	.13	—	.72	.17	.51

the eight weeks of the experimental period, and three weeks after, are shown in Table IX. Weekly averages for individual cows are presented in Table X.

(1) *Liveweights*: The summary in Table XI and the graphical representation (Fig. 3) show that on an average the twins of the turnips group were heavier than their co-twins in the three weeks preceding the experiment. From the beginning of the experimental period, however, they lost weight to such an extent that they averaged, at the end of the fourth week, nearly 30 lb. lighter than the silage-fed cows. After this, they began to regain condition, but were still slightly lighter at the end of the experiment. All twin sets except T211—T212 (see Table X) showed a similar trend. When allowance was made

TABLE XI. MEAN BODYWEIGHTS AND PRODUCTIONS

	Group	Average 3 weeks before experiment	Average 8 weeks experiment	Average 3 weeks after experiment
Bodyweights (lb.)	T	769	749	782
	S	747	752	745
	Diff.	22	—3	37
Milk (lb.)	T	159.9	133.8	84.1
	S	160.8	123.5	88.8
	Diff.	—0.9	10.3	—4.7
Butterfat (lb.)	T	6.90	5.98	4.32
	S	6.88	5.47	4.26
	Diff.	.02	.51	.06
Butterfat (%)	T	4.32	4.47	5.14
	S	4.28	4.43	4.79
	Diff.	—.02	.04	.35

for initial weight variation (Table XII), a significant treatment difference of 29 ± 12.3 lb. was demonstrated in favour of the silage-fed group. However, immediately after the conclusion of the experiment (see Table IX) the weight relationship between the groups returned to the original position. This rapid change suggests that the "true" bodyweights of both groups of twins remained practically unaffected and that the apparent loss of bodyweight caused by turnip feeding was due to its scouring effect.

(2) *Yields*

(a) *Milk*: In all eight weeks of the experimental period the turnip-fed cows produced more total milk than the silage-fed cows (Table IX). The responses of the twin sets to the treatments were, however, not quite consistent, some turnip-fed cows even producing

TABLE XII. ANALYSIS OF COVARIANCE: LIVEWEIGHT, MILK YIELD, BUTTERFAT YIELD AND BUTTERFAT PERCENTAGE
(lb. per week)

(Complete experimental period only)

x = pre-treatment period (3 weeks)
y = experimental period (8 weeks)

Source of variation	Sums of squares and products				Deviations from regression		
	df	(x^2)	(xy)	(y^2)	df	ss	ms
a. **Liveweight**							
Treatments	1	2091	—259	32	—	—	—
Twin sets	8	259369	239610	222185**	—	—	—
Residual (Treatments x sets)	8	3939	4795	8959	7[1]	3122	446
Treatments + Residual	9	6030	4536	8991	8	5579	—
Treatments (adjusted)	—	—	—	—	1	2457	2457*
Sets + Residual	16	263308	244,405	231144	15	4285	—
Sets (adjusted)	—	—	—	—	8	1163	145.4
b. **Milk Yield**							
Treatments	1	4	—41	481	—	—	—
Twin sets	8	24131	19488	17407**	—	—	—
Residual	8	699	588	944	7[2]	449	64
Treatments + Residual	9	703	547	1425	8	1000	—
Treatments (adjusted)	—	—	—	—	1	551	551*
Sets + Residual	16	24830	20076	18351	15	2118	—
Sets (adjusted)	—	—	—	—	8	1669	209
c. **Butterfat Yield**							
Treatments	1	0	.06	1.18*	—	—	—
Sets	8	32.56	28.75	27.11**	—	—	—
Residual	8	1.00	.09	1.35	7[3]	1.34	.19
d. **Butterfat percentage**							
Treatment	1	.0013	—.0009	.0007			
Twin sets	8	7.58	6.47	5.82			
Residual	8	.24	.02	.09			

[1] b = 1.2** Adjusted treatment difference: —3—22b = —29 ± 12.3 lb.
[2] b = 0.84 Adjusted treatment difference: 10.3 + 0.9b = 11.1 ± 3.8 lb.
[3] Regression not significant. Treatment difference: 0.51 ± .19.

*Significant at 5%.
**Significant at 1%.

less than their co-twins (see Table X). Such inconsistencies could be explained in large measure by pre-treatment differences. Allowing for these differences (see analysis of co-variance, Table XII b), it was found that the treatment difference was significant (11.1 ± 3.8 lb. per week and per cow, or approximately 9 per cent). By using log transformation, the magnitude of the systematic effects (regression, treatments and sets) relative to the "residual" (unexplained) variation was increased. This indicates that the treatment effect was to some extent proportional to the level of producion of the twin sets.

Although the overall treatment x weeks interaction was not significant, its linear component was, i.e. the treatment difference increased significantly as the trial proceeded (Table XIII and Fig. 3). It is to be noted that the overall milk production was falling markedly in the course of the trial; the percentage treatment difference, therefore, increased to an even greater extent.

The beneficial effect of feeding turnips was very transient: already at the end of the first week after the cessation of the trial the productions of the two groups were practically equal. Thereafter, the group previously fed on turnips actually produced less milk than the other group.

TABLE XIII. ANALYSIS OF VARIANCE—WEEKLY MILK AND BUTTERFAT YIELDS (lb.)

(Mean squares only)

Source of variation	df	Milk	Butterfat
Treatments	1	385	9.46**
Weeks	7	7284**	10.37**
Linear Regression	1	47101**	61.87**
Deviations	6	648**	1.79**
Twin sets	8	17407**	27.11**
Treatments x weeks	7	83	.21
Linear Regression	1	287*	1.28*
Deviations	6	49	.03
Treatments x Sets	8	944**	1.35**
Weeks x Sets	56	102**	.19
Residual (Treatments x weeks x sets)	56	45	.13

(b) *Butterfat*: The turnip-fed cows produced more total butterfat than their silage-fed co-twins in each week of the experimental period (Table IX and Fig. 3). The analysis of variance (Table V c) shows that the average difference of 0.51 ± .19 lb. per cow per week (or approximately 9 per cent) was significant ($P = 0.035$). In contrast to milk yield, the butterfat productions over the experimental period were not affected significantly by the pre-treatment yields (after allowance was made for between-set differences). There was little

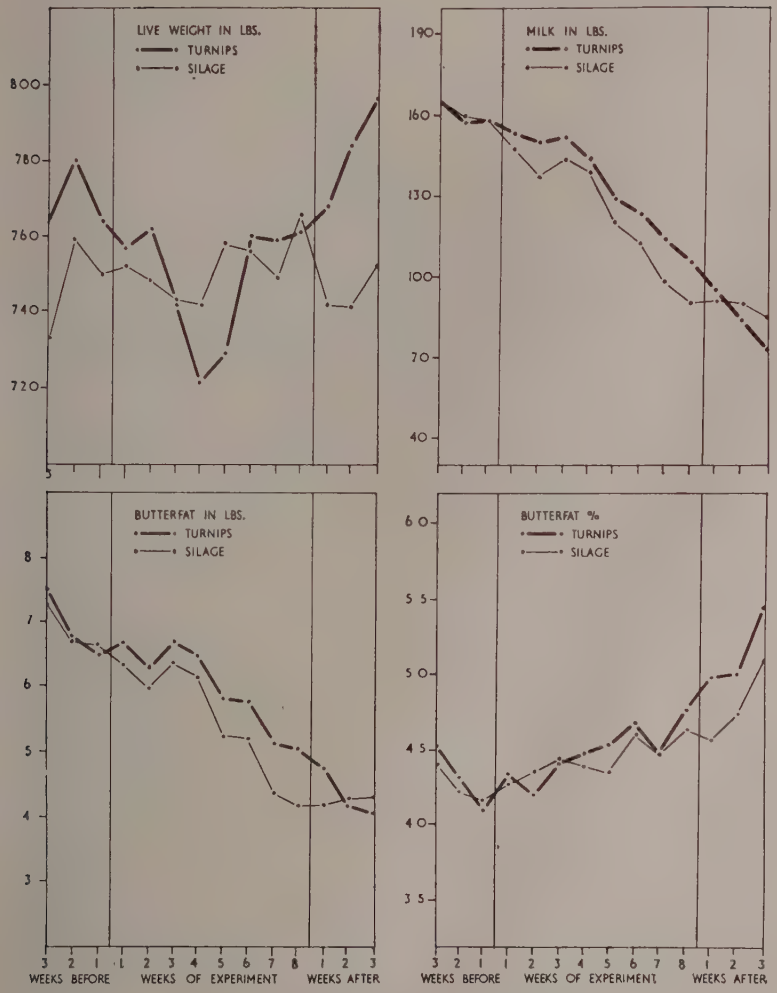

FIG. 3.—Mean growth and production curves

indication that the effect of treatments was proportional to the level of butterfat production of the twin sets.

From Table IX it can be seen that the treatment difference remained fairly constant at approximately $\frac{1}{3}$ lb. per cow per week for the first half of the experimental period and then tended to increase, to reach 0.86 lb. in the last week. There was, however, no significant evidence of departure from a linear trend (Table XIII), this linear increase being itself significant. As the overall butterfat yield declined significantly in the course of the experiment and the absolute treatment differences tended to increase, it naturally follows that the percental differences increased at an even greater rate. The treatment-x-set interaction term proved

highly significant (Table XIII); Table X shows that the several twin sets reacted differently to the treatments. At one end of the scale the set T190–T189 showed an average weekly difference of 1.25 lb. in favour of the turnip-fed twin, while at the other end the turnip-fed twin (T94) averaged 0.40 lb. less than her co-twin (T93). It is not possible to gauge to what extent true environment x genotype interaction contributed to this variation, and how much was due to not easily controllable environmental factors influencing one twin but not her mate.

The rate of decline in butterfat production shown by the turnip-fed cows relative to their silage-fed co-twins during the after-period was not as great as in the case of their milk yield (see Fig. 3). This was due to the higher fat content of the milk of the turnip-fed cows during this period. Nevertheless, by the second week of being pastured together the average butterfat productions of the two groups were already approximately the same.

(c) *Butterfat percentage*: Although the turnip-fed cows produced, during the experimental period, milk of slightly butterfat test than the silage-fed group, the difference of 0.04 per cent was far from significant (Table V d). In the after-period an immediate rise occurred in the fat percentage of the cows previously fed on turnips (Fig. 3). The reason for this increase, which was quite consistent (Table X), is obscure, but was probably connected with the rapid decline in milk production of this group.

Discussion and Conclusions

This trial has shown that turnips are better as milk-producing fodder than average-quality grass silage during the dry summer period, which, in New Zealand, coincides with the declining phase of lactation. The beneficial effect of turnips on butterfat production was specially noted when the grass growth deteriorated during the last four weeks of the trial. The absolute magnitude of the treatment effects should not be given undue emphasis, in view of the relatively few twin sets used, and in view of the fact that only one sample of silage could be tested.

The fact that a relatively small average treatment difference could be shown significant, despite the small number of experimental animals employed, indicates in general terms the efficient use that can be made of identical twins in an experiment of this type. The reason lies in the possibility of eliminating the large between-set (i.e. genotypic and permanent environmental) variation (see Table XIII).

Acknowledgments

The author wishes to record his thanks to Mr. W. Ritchie for care of experimental animals and to Mrs. A. Clarke for the butterfat tests. He is also grateful to Dr. A. H. Carter for statistical advice and helpful discussion, and to Miss J. Webster for the computational work. Finally, he wishes to express his appreciation to Dr. C. P. McMeekan for encouragement and constructive criticism.

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MEASUREMENT OF FEED INTAKE BY GRAZING CATTLE AND SHEEP

III. MARKER TECHNIQUE FOR INVESTIGATING THE FAECES OUTPUT OF GRAZING COWS

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Summary

1. Faeces from three cows grazing pasture were collected over a period of 40 days. Chromic oxide fed to the cows during the period was quantitatively recovered from the faeces (102, 100, and 102 per cent respectively).

2. From the concentration of chromic oxide in "grab" samples of faeces, the quantity of faeces voided over periods of five days by any cow could be calculated with a coefficient of variation of about 10 per cent.

Introduction

In the first paper of this series[1] it was pointed out that progress in studies on the nutrition of grazing animals was limited by the lack of an efficient method of estimating their grass consumption. A method was proposed whereby the digestibility of herbage consumed by sheep could be estimated from the nitrogen content of the animals' faeces. A relationship such as this, combined with the determination of faeces output, permits the estimation of the amount of herbage consumed by the grazing animal.

To measure the intake of pasture by milking cows at this Station, a technique has been designed to fit in with the normal grazing management of the cows, which are available for intake measurement only twice daily at milking. At this time, each cow is dosed with chromic oxide and a faeces sample ("grab" sample) is obtained, either by removal manually from the rectum or from a natural defaecation if this happens at the sampling time. Each grab sample, or a composite sample made by bulking a number of samples over a suitable period, is analysed for chromic oxide, nitrogen and ash, from which data the consumption of grass organic matter by each cow is estimated.

A preliminary experiment designed to test the essential features of this technique was conducted in April, 1948. In this experiment, the faeces output by three grazing cows, estimated by the chromic oxide technique, was compared with output measured by total collection using the "bagging" procedure. The grass consumption by each cow was estimated from the faeces output data using digestibility coefficients obtained (a) by calculation from the nitrogen concentrations in the cows' faeces, and (b) by means of digestibility trials with sheep fed pasture obtained from the area grazed by cows. These estimates of intake were compared with estimates derived from the quantity of grass remaining in protected enclosures in the grazing area after the cows had completed grazing.

This paper presents the results obtained in the estimation of faeces output.

EXPERIMENTAL PROCEDURE

Objects of the Experiment

The experiment was carried out to test the validity of two assumptions on which the technique depends:

(1) That chromic oxide fed over a given period is quantitatively voided over a corresponding period;

(2) That when chromic oxide is administered in a capsule twice daily, it is sufficiently well dispersed within the gut contents to enable its concentration in grab samples of faeces taken twice daily to represent that in the whole faeces.

If these assumptions are valid, the faeces organic matter output (E) can be calculated from the relationship

$$E = \frac{g}{c}$$

where g = quantity of chromic oxide consumed over the period;

c = the concentration (organic matter basis) of chromic oxide in grab samples of faeces taken during a corresponding period.

In what follows all reference to the quantity of faeces voided will be on an organic matter basis. This has been adopted throughout in preference to dry matter to eliminate the effect of the variable and sometimes high contamination with soil.

Design of Experiment

An area of about 4 acres of dairy pasture was closed from grazing in late autumn (April) 1948, and by the time the experiment started at the beginning of May the herbage was 4 to 6 in. high, its botanical composition being approximately 60 per cent *Lolium perenne*, 20 per cent *Dactylis glomerata*, 10 per cent *Holcus lanatus* and 10 per cent *Trifolium* spp.

Three dry non-pregnant cows were allowed to graze *ad lib.* for twelve days on a subdivision of the grazing area described. At the end of this preperiod the measurement trial began, and continued for forty days. Each day the cows were moved into a fresh area of pasture of approximately one twelfth acre, to which they were confined by means of electric fences. Although the grazing area was restricted, the grass available was more than sufficient to meet the animals' requirements. During the experiment the animals gained in weight by an average of about fifty pounds.

At the usual milking times, 6 a.m. and 4 p.m. daily, a gelatine capsule containing 7.5g. chromic oxide pigment suspended in gelatine was administered to each cow by means of a balling gun. Dosing commenced on the 8th day of the *ad lib.* grazing preperiod. Two days later the harness and collection bags were fitted to the cows to condition them, and the collection of faeces started on the first day of break grazing, which was five days after the commencement of dosing.

The chromic oxide content of all faeces samples was estimated by the method described by Coup and Lancaster[2]. The ash content of all samples was also estimated.

RESULTS AND DISCUSSION

Recovery of Chromic Oxide

The first task was to determine if the output of chromic oxide over a period was equal to the intake. The faeces collected over each half day from each cow were weighed. After thorough mixing of the faeces, "representative" samples of about one half pound were withdrawn and analysed individually for chromic oxide. From these analyses the total amount of chromic oxide in each collection of faeces was calculated, and the results are expressed in Table I as percentage of intake over five-day periods. Although there was some variation between the periods, the output over the forty days approximated closely to the intake.

At each collection a sample of 5g. per pound of faeces was weighed into a tared tin, dried at 100 to 105°c for 48 hours and re-weighed, thus providing data for dry matter estimates. Using the dried faeces, bulked representative samples were accumulated over five-day periods. The recoveries of chromic oxide obtained by analysis of these samples are presented in Table I. The close agreement between results from the two sets of samples indicates the accuracy of the bulking and analytical techniques.

This observation is of some importance, since future investigations can be greatly simplified by omitting the analysis of numerous representative samples and relying solely on data from bulked representative samples, as is normally done in digestibility trials.

Grab samples taken from each cow at bag-changing times were analysed for ash and chromic oxide. In anticipation of the practical necessity to reduce analytical work on the large number of grab samples which might be taken in future investigations, the effects of bulking them on the estimates of faeces output were investigated. Fifty-gram samples of fresh faeces were taken from each grab sample and were dried and bulked for each cow for every five-day period, giving bulked grab samples.

Data from representative and grab samples compared

The representative samples taken at the afternoon and morning bag changes were representative of faeces collected during the day and night periods respectively. A grab sample taken at these times can be considered only as a random sample of faeces in a cow's rectum at the time of sampling. As the intention is to use grab samples to represent the whole faeces, it is pertinent to compare the concentration of chromic oxide obtained in the two series of samples.

Such comparisons are provided in Fig. 1 in which concentrations of chromic oxide in each sample are plotted against sampling time.

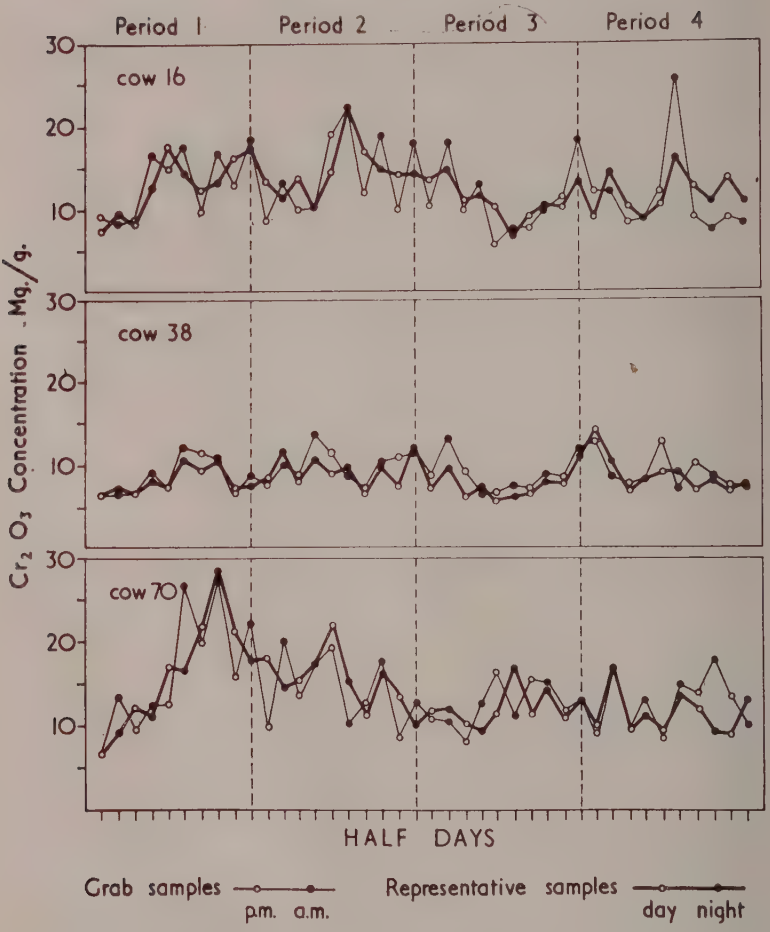

FIG. 1.—Variations in Concentration of Cr_2O_3 in Faeces Samples.

Study of the graphs shows:

(1) In general, the concentrations of chromic oxide in grab and representative samples were similar, and similar periodic changes (periods greater than one day) were shown by the two types of samples.

(2) Daily fluctuations were shown by both series of samples, though they were rather more pronounced with the grab samples.

(3) Afternoon grab samples tended to contain lower concentrations of chromic oxide than adjacent morning samples. Similar, though less pronounced, diurnal variations were shown by the day and night representative samples.

These observations are summarised in Table II which shows the mean concentrations of chromic oxide (40 days) in the various types of samples considered. It can be seen that the mean concen-

TABLE. I. PERCENTAGE CHROMIC OXIDE RECOVERY AND TOTAL FAECES ORGANIC MATTER OUTPUT

Cow	Sample	Results over successive 5 day periods								40 day period
		1	2	3	4	5	6	7	8	
16	Representative	111	97	102	95	108	95	105	102	102
	Bulked Representative	110	96	101	97	107	94	104	100	101
	Total Faeces (Kg.)	(6.2)	(4.7)	(6.6)	(6.0)	(7.2)	(6.8)	(7.2)	(7.9)	(52.7)
38	Representative	100	110	90	106	101	100	90	99	100
	Bulked Representative	100	110	95	101	102	96	90	98	99
	Total Faeces (Kg.)	(8.7)	(8.3)	(8.9)	(8.8)	(10.0)	(8.7)	(9.0)	(10.0)	(72.3)
70	Representative	90	102	119	110	95	109	94	93	102
	Bulked Representative	91	102	118	108	95	106	99	94	102
	Total Faeces (Kg.)	(4.4)	(5.2)	(6.9)	(7.0)	(7.1)	(7.3)	(7.8)	(7.3)	(53.1)

TABLE II. MEAN Cr_2O_3 CONCENTRATION IN FAECES SAMPLES (40 DAYS) (Mg./g. organic matter)

Samples	Cow 16		Cow 38		Cow 70	
Grab	p.m. 9.54	a.m. 12.58	p.m. 8.27	a.m. 8.55	p.m. 11.10	a.m. 13.23
Representative	day 10.62	night 11.67	day 7.29	night 8.40	day 10.68	night 12.23
Bulked grab	10.96		8.38		12.02	
Bulked representative	11.04		7.79		11.16	

Grab Samples taken from rectum at 4 p.m. and 6 a.m.
Representative Samples taken from bags at bag changes (4 p.m., 6 a.m.).
Bulked Grab Samples: Grab samples bulked on *equal weight* basis over 5-day periods.
Bulked Representative Samples: Weights of representative samples, proportional to the weight of faeces excreted, bulked over 5-day periods.

trations in the night representative samples were about 12 per cent higher than in the day samples from each cow. The differences shown by the grab sample means were much more variable.

Diurnal variations in marker concentrations could obviously reduce the efficiency of grab samples, since concentrations in these samples represent two points in a daily concentration curve. Ideally, sampling times should be determined by the characteristics of this curve (c.f. Kane *et al.*[3]) but, practically, this was not possible. It happened in this experiment, however, that the mean concentrations of marker in grab samples approximated to those in representative samples (Table II). Other experimental conditions might modify the picture with consequent bias in results obtained from grab samples. This problem is under investigation.

Estimation of Faeces Output from Grab samples

Estimates of faeces organic matter output based on the Cr_2O_3 content of the organic matter of grab samples and calculated by means of the formula $E = \frac{c}{g}$ are shown in Table III as percentage of actual output.

Estimates have been made from morning samples only (a.m.), evening samples only (p.m.), and from all samples (p.m. + a.m.). In all cases the daily faeces outputs have been calculated from each sample in each series of grab samples and these have been totalled over five-day periods. Estimates of faeces output over five-day periods have also been made from the bulked grab samples.

It is recognised that the use of faeces samples bulked on an equal weight (and therefore non-aliquot) basis will introduce bias into subsequent estimates of faeces output. Such a bias is illustrated by comparison of bulked grab samples with p.m. + a.m. samples (Table III). The estimates from bulked samples were some five per cent lower, a difference attributed largely to the effect of non-aliquot bulking.

In view of the daily fluctuations in concentration of chromic oxide in grab samples, the differences between estimates of faeces output based on the p.m. samples and estimates based on the a.m. samples are to be expected. Biased estimates resulted when p.m. or a.m. samples alone were used, though by combining the data from these samples the bias was considerably reduced.

Bias need not contribute to the error of estimates providing the bias is consistent and common to all cows, since a satisfactory correction could be applied. The biases (B) and errors (as coefficients of variation (v)) associated with the various estimates of faeces are presented in Table IV. It is obvious from the table that the biases in estimates from a given series of samples were not similar for all cows, hence correction for bias was not justified. In calculating the coefficients of variation, therefore, bias has been ignored.

The data quoted under "All cows" (Table IV) provides a summary of the results of the experiment. It may be concluded that faeces output by individual cows over five-day periods was estimated from individual grab sample data with a coefficient of variation of 10 per cent, and that little additional error resulted from the bulking of these samples.

TABLE III. ESTIMATES OF FAECES OUTPUT

	Combinations of grab samples	Estimates expressed as percentage of actual faeces over successive 5-day periods								
		1	2	3	4	5	6	7	8	Total
Cow 16	Bulked	88	108	100	99	93	115	99	102	100
	p.m. + a.m.	95	118	110	123	96	114	101	110	108
	p.m.	109	137	130	126	102	119	116	124	120
	a.m.	81	99	91	120	89	108	86	95	96
Cow 38	Bulked	98	86	97	89	88	100	105	92	94
	p.m. + a.m.	101	91	98	96	88	110	103	92	97
	p.m.	112	100	105	86	87	110	107	87	99
	a.m.	91	81	92	105	89	109	98	97	95
Cow 70	Bulked	99	98	82	85	99	81	88	101	91
	p.m. + a.m.	116	104	86	84	106	89	94	106	97
	p.m.	144	115	88	96	121	98	96	112	107
	a.m.	89	94	84	72	91	81	93	101	88

Mean of all cows for 40 days: 95, 101, 109, 93 per cent respectively for the four combinations of samples.

TABLE IV. ERRORS AND BIASES IN FAECES ESTIMATES FROM GRAB SAMPLES

Grab samples used	Cow 16		Cow 38		Cow 70		All cows	
	B	v	B	v	B	v	B	v
From p.m. + a.m.	7.2*	10.9	—3.0	7.7	—2.8	10.9	0.3	9.7
From p.m.	16.4**	18.2	—1.1	10.7	6.2	14.3	6.8*	14.5
From a.m	—4.4	13.0	—4.9	9.8	—13.7**	17.2	—7.2**	12.9
From bulked	0.4	7.6	—6.1*	9.1	—9.8*	13.6	—5.1**	10.1

B = bias (%) (estimated minus actual faeces as per cent actual faeces).
v = coefficient of variation (Standard error (ignoring bias) as per cent actual faeces).
* Significant at 5%.
** Significant at 1%.

TABLE V. "ERROR" VARIANCES OF FAECES ESTIMATES (5-DAY TOTALS)
($Kg^2 \times 10^4$)

	Bulked representative samples (Vm + Ve)	Bulked grab samples (Vm + Ve + Vg)	Difference (Vg)	Per cent of Total
Cow 16	11.5	25.6	14.1	55.1
Cow 38	22.6	59.9	37.3	62.3
Cow 70	31.7	67.6	35.9	53.1
All Cows	21.9	51.0	29.1	57.1

Presentation of the results in the condensed form of Table IV has necessitated the exclusion of some useful information brought out by the regression analysis of the data. Given the estimated faeces (E) and the corresponding actual faeces (F), the theoretically "best" prediction formula is the derived regression equation of E on F. From the appropriate statistical analysis of the data two main conclusions were drawn:

(1) Faeces output could be predicted (from this specific data) as accurately from a.m. grab samples alone as from p.m. and a.m. samples together.

(2) The prediction equations differed significantly for the three experimental animals. In virtue of (2) it is clear that no satisfactory formula of general applicability can be derived from this restricted data.

Sources of Error

It is evident that errors in the estimation of faeces output from bulked grab samples are likely to be substantial. An attempt has therefore been made to define and evaluate them.

These errors are traceable to breakdown in the assumptions referred to under "Objects of the experiment" above. Since the bulked representative samples were taken from the total collected faeces after thorough mixing, the chromic oxide content of these samples may be accepted as properly weighted mean concentrations of the marker in total faeces over the period concerned. It seems reasonable to assume, therefore, that the error variances of the estimates of faeces output based on bulked *representative* samples are composed of two independent components associated with:

(1) Uneven excretion of marker (Vm);

(2) Experimental error (measurement of faeces organic matter output, marker concentration and other small errors) (Ve).

Using bulked *grab* samples, however, an additional error component will be associated with

(3) Non representativeness of marker concentration due to sampling variations, and bias associated with non-aliquot bulking.

If it be assumed that this error (Vg) is independent of the previous two, its magnitude may be estimated as the difference between the error variances associated with bulked *representative* and bulked *grab* samples. The results of the analysis of the data along these lines are presented in Table V.

It appears from Table V that nearly half of the error variance associated with the use of bulked grab samples is due to factors not ascribable to faults in grab samples *per se* (c.f. (3) above), but to the experimental procedure as a whole. These errors could be reduced by increasing the length of period and improving if possible the efficiency of mixing chromic oxide with gut contents.

The experiment was obviously too limited in terms of cattle population and environment to enable a generally applicable estimate

of the accuracy of the marker-grab sample technique to be made. It has, however, demonstrated the usefulness of the technique when applied to grazing cows, and has provided some idea not only of the order of accuracy attainable, but also of the sources and magnitude of component errors.

Further work has been carried out at this Station with a view to obtaining the data necessary to extend the range of applicability of the method. For those studies, a fourteen-day experimental period was selected, as one of convenient length. While it is still too early to present detailed conclusions upon the outcome of these studies, results to date indicate that, under a wide variety of experimental conditions, the quantity of faeces excreted by a cow over a fourteen-day period may be estimated with an error of about 10 per cent.

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NUTRIENT UPTAKE BY GLASSHOUSE TOMATO PLANTS

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Summary

Analyses of whole plants divided into leaves, stems, and fruits have been carried out at different stages of growth.

Certain changes in the chemical composition of the plant as the season progressed have been found.

The total weight of fruit produced by the end of the season was found to contain the major part of the dry-matter, nitrogen, phosphate and potash of the plant. This was particularly true of potash.

The periods of most rapid growth and nutrient intake have been determined..

The fertilizer requirements of the crop as suggested by these experiments are discussed.

Introduction

Work at the Cheshunt Experimental Station has shown the large quantity of plant nutrients taken up by tomatoes grown in heated houses under English conditions.[1] It was thought desirable to obtain similar data for Nelson tomatoes, grown in unheated houses in a warmer and more sunny climate. The uptake of plant nutrients during different periods of growth and the relative amounts present in leaves, stems and fruits have also been determined. The data have given some information on the amount of fertilizer required for the production of a satisfactory crop under local conditions.

Experimental Procedure

The experiment was carried out on plants grown in an unheated glasshouse. The soil was a clay loam, neutral in reaction with exchangeable bases of approximately calcium 20 m.e., magnesium 7 m.e. and potassium 1 m.e. per 100 g. The total nitrogen was not high, producing not more than 55 p.p.m. of total available nitrogen by planting time as a result of winter steam-sterilization of the soil. The standard fertilizer used for these plants supplied during the season some 4½ oz of nitrogenous fertilizer consisting mainly of dried blood and sulphate of ammonia, 10 oz of superphosphate and 5 oz of muriate of potash per square yard. These quantities represent 12.2 cwt, 27 cwt, and 13.5 cwt per acre respectively. Times of application during the two seasons of the experiment are shown in Table I.

The houses were planted in the third week in August and the crop began to ripen late in November. The plants were not topped. Whole plants were harvested at intervals throughout the main growing period and divided into leaves, stems and fruit. The fruit sample included the green fruit on the plant at the time of harvesting and fruit which had ripened previously. The leaf sample included the petioles, and the

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TABLE I. STANDARD FERTILIZER TREATMENT
(Expressed as oz. per sq. yd.)

	Winter	12-10-49 11-10-50	7-11-49 14-11-50	14-12-49 13-12-50	Total
Dried blood plus sulphate of amonia 1 : 1	—	1.5	1.5	—	*
Dried blood plus nitrate of soda 1 : 1	—	—	—	1.5	4.5
Superphosphate	4	2	2	2	10
Muriate of potash	2	1	1	1	5

* The total nitrogenous fertilizers applied are equivalent to approximately 3.6 oz. of sulphate of ammonia per sq. yd.

stem sample contained a small weight of flowers and calyces. Prunings were discarded. Records were taken of fresh and dry weights (dried at 100° c) and the samples were analysed for plant nutrients. Five plants were sampled at each date. In drawing conclusions from the analytical data, it was assumed that the plants were sufficiently uniform for the behaviour of any five to be representative of the behaviour of the whole.

RESULTS

Dry-Matter and Plant Nutrient Content of Plants at Different Stages of Development

Analyses of plants sampled in the 1949-50 season are shown in Table II.

It will be seen (Table II) that certain changes in composition of the plant were found as the season progressed. A drop in the percentage of dry-matter was apparent in plants harvested in mid-season. The leaves showed a tendency to rise in percentage of calcium and phosphate with age of the plant and to decrease in potash and nitrogen. In the stems such changes were not apparent except for potash. Differences in composition of the fruit did not appear to be related to the age of the plant.

The experiment was repeated in the following year on a plot treated with extra potash. A winter dressing of one ton per acre of muriate of potash was applied in addition to the standard fertilizer. Analytical data for plants on this plot are shown in Table III.

Results in Table III are comparable with those obtained in the previous season (Table II) except that potash appears to have been raised to some extent by the extra ton per acre of muriate of potash. Calculated as grammes per plant the uptake of nitrogen and phosphate was found to be almost identical over the same periods in both seasons. In 1950-51, the plants did not drop to such a low dry-matter percentage in mid-season as in the previous season. This may have been due to different weather conditions or to the higher potash content of the soil.[2] Certain changes in composition were again apparent with increasing age of the plant. In fruits, stems and leaves, the percentages of potash were higher in young plants than in old plants. For phosphate, the reverse was true in the leaves and stems.

TABLE II. ANALYSES OF TOMATO PLANTS—SEASON 1949-50

	Date of Sampling	Fresh Weight per plant (g.)	Dry Weight per plant (g.)	Dry Matter (%)	Calcium (CaO) (%)	Magnesium (MgO) (%)	Nitrogen (N) (%)	Phosphate (P_2O_5) (%)	Potash (K_2O) (%)
Leaves	27-10-49	218	25.6	11.7	7.98	2.66	3.58	0.70	2.80
	28-11-49	394	44.0	11.2	7.24	2.23	3.20	0.72	2.90
	29-12-49	510	44.9	8.8	8.88	2.40	2.89	0.94	2.52
	26- 1-50	790	88.6	11.2	8.29	2.77	2.72	1.17	2.36
Stems	27-10-49	93	9.5	10.2	2.01	1.37	1.82	0.89	5.70
	28-11-49	216	23.9	11.1	2.03	1.21	1.53	0.83	5.32
	29-12-49	295	29.7	10.1	2.09	1.22	1.61	0.87	5.24
	26- 1-50	497	58.0	11.7	2.08	1.43	1.56	1.05	4.59
Fruit	27-10-49	362	23.0	6.4	0.28	0.28	2.36	0.91	5.27
	28-11-49	1603	81.6	5.1	0.27	0.34	2.45	0.92	5.90
	29-12-49	3317	137.4	4.1	0.37	0.22	2.63	1.20	7.43
	26- 1-50	4893	227.8	4.7	0.18	0.29	2.17	0.96	5.70

TABLE III. ANALYSES OF TOMATO PLANTS—SEASON 1950-51

	Date	Fresh Weight per plant (g.)	Dry Weight per plant (g.)	Dry Matter (%)	Nitrogen (N) (%)	Phosphate (P_2O_5) (%)	Potash (K_2O) (%)
Leaves	30-10-50	184	22.2	12.1	3.54	0.85	3.39
	15-11-50	269	27.4	10.2	3.61	0.84	3.80
	14-12-50	461	50.4	10.9	2.93	0.81	3.15
	11- 1-51	605	65.6	10.8	2.76	0.94	2.46
	5- 2-51	744	84.8	11.4	2.58	1.38	2.24
	2- 3-51	813	93.2	11.5	2.36	1.31	2.43
Stems	30-10-50	106	11.2	10.6	1.84	1.02	6.09
	15-11-50	173	18.2	10.5	1.61	0.99	6.26
	14-12-50	251	29.6	11.8	1.44	0.91	5.61
	11- 1-51	319	39.4	12.3	1.37	0.94	4.88
	5- 2-51	433	53.6	12.4	1.44	1.16	4.58
	2- 3-51	523	59.4	11.4	1.58	1.25	4.93
Fruit	30-10-50	243	14.2	5.8	2.73	1.34	7.37
	15-11-50	805	38.6	4.8	2.69	1.24	7.78
	14-12-50	2357	107.6	4.6	2.54	1.23	7.92
	11- 1-51	3615	188.8	5.2	2.25	1.06	6.97
	5- 2-51	4560	239.0	5.2	2.25	1.20	6.68
	2- 3-51	5429	273.8	5.0	2.28	1.12	6.66

Dry-Matter and Plant Nutrients in Leaves, Stems and Fruits

The analyses (Table III) showed that as the season progressed the fruit constituted the major part of the weight of the plant and contained a high proportion of the total nitrogen, phosphate, and potash absorbed. The amounts of these constituents expressed in grammes per plant and the percentages of the total found in leaves, stems and fruits of the mature plants sampled on 2 March are shown in Table IV.

It will be seen from Table IV that under the conditions of this experiment the fruit formed nearly two thirds of the total dry-weight of the plant and that amounts of nitrogen, phosphate and particularly potash, associated with the fruit were correspondingly high. The speed of formation and growth of fruit would therefore be the main factor governing the demand on the soil for potash, and to a lesser extent for nitrogen and phosphate.

Rate of Growth and Nutrient Intake

Table V shows the rate of growth of leaves, stems and fruit in periods between the sampling dates as measured by increases in dry-matter. (Calculated from data in Table III.) The intake by the whole plant of nitrogen, phosphate and potash during these periods is also given. The figures represent the average weight increases per day, the maximum values for the season being underlined.

Table V shows that the maximum rate of growth of the whole plant as measured by the increase in total dry-matter was found for the period 14 December to 11 January. This corresponded with the greatest increase in weight of fruit. The data indicate an increased leaf production early in December followed by a considerable decrease when fruit development was at its highest (14 December to 11 January). A similar tendency for decreased leaf growth at the period of greatest increase in fruit weight was found in the previous season (Table II). The vegetative parts of the plant appeared to have made little growth during December (Table II cf. 28-11-49 and 29-12-49). This slowing of vegetative growth at the height of the season is quite common under local conditions and is often accompanied by some flower-drop in the upper bunches. Table V shows a rise for both leaves and stems in late January as fruit production slowed. Speed of growth for all parts of the plant was much reduced in February.

Though potash uptake is more influenced by the demands of the fruit than of other parts of the plant, it reached a maximum rate before the times of maximum fruit increase and was related to the high percentage of potash in the young plant. The same applies to nitrogen. Both leaves and fruit showed a maximum intake of potash and nitrogen at this time (15 November to 14 December). The highest phosphate uptake was found much later (for the period 11 January to 5 February), reflecting the increased leaf and stem formation at this time and the increase in percentage of phosphate with age of the plant.

Fertilizer Requirements

The data in Table III have been used in Table VI to calculate the nutrient uptake during the season by plants producing a total of 60 tons of fruit (based on the total yield figures for 2 March). The quantities are expressed as ounces per square yard on a basis of 60 tons of fruit per acre, equivalent to approximately 9 lb. per plant, which is a satisfactory yield under local conditions.

TABLE IV. QUANTITIES OF DRY-MATTER, NITROGEN, PHOSPHATE AND POTASH IN DIFFERENT PARTS OF THE MATURE PLANT
(Sampled 2 March)

	Fresh Weight		Dry-Matter		N		P_2O_5		K_2O	
	per plant (g.)	Percentage of total	per plant (g.)	Percentage of total	per plant (g.)	Percentage of total	per plant (g.)	Percentage of total	per plant (g.)	Percentage of total
Leaves	813	12.0	93	21.8	2.20	23.5	1.22	24.3	2.26	9.6
Stems	523	7.7	59	13.9	0.94	10.0	0.74	14.7	2.93	12.5
*Fruit	5429	80.3	274	64.3	6.24	66.5	3.07	61.0	18.24	77.9
Total	6765		426		9.38		5.03		23.43	

* Includes earlier pickings of ripe fruit.

TABLE VI. NITROGEN, PHOSPHATE AND POTASH ABSORBED BY PLANTS YIELDING 60 TONS OF FRUIT
(Expressed as equivalent of fertilizer in ounces per sq. yd. on a basis of 60 tons tons per acre or 9 lb. per plant.)

	Planting to 30-10-50	30-10-50 to 15-11-50	15-11-50 to 14-12-50	14-12-50 to 11- 1-51	11-1-51 to 5-2-51	5-2-51 to 2-3-51	Total	Total from previous expt.	Total supplied in Std. Fert.
Sulphate of ammonia	0.56	0.39	0.95	0.80	0.71	0.43	3.84	3.74	3.6
Superphosphate	0.20	0.16	0.46	0.40	0.69	0.15	2.06	1.74	10.0
Muriate of potash	0.41	0.44	1.08	0.81	0.59	0.51	3.84	3.22	5.0

TABLE V. AVERAGE DAILY FORMATION OF DRY-MATTER AND INTAKE OF NITROGEN, PHOSPHATE AND POTASH DURING PERIODS BETWEEN SAMPLINGS

(Expressed as mg. per plant)

	30-10-50 to 15-11-50	15-11-50 to 14-12-50	14-12-50 to 11- 1-51	11-1-51 to 5-2-51	5-2-51 to 2-3-51
Dry-Matter					
Leaves	325	**793**	543	768	336
Stems	438	393	350	**568**	232
Fruit	1525	2380	**2900**	2008	1392
Total	2288	3566	**3793**	3344	1960
Nitrogen (N)					
Leaves	12.6	**16.8**	11.9	15.1	0.5
Stems	5.4	4.6	4.1	**9.3**	6.6
Fruit	40.8	**58.5**	54.0	45.3	34.4
Total	58.8	**79.9**	70.0	69.7	41.5
Phosphate (P_2O_5)					
Leaves	2.6	6.1	7.4	**22.1**	2.0
Stems	4.1	3.1	3.6	**10.1**	4.8
Fruit	18.0	29.1	24.2	**34.7**	7.9
Total	24.7	38.3	35.2	**66.9**	14.7
Potash (K_2O)					
Leaves	18.1	**18.8**	0.9	11.4	14.6
Stems	**28.6**	17.9	9.4	21.3	19.0
Fruit	122.3	**190.3**	165.6	112.2	90.8
Total	169.0	**227.0**	175.9	144.9	124.4

From Table VI, assuming an adequate supply of these nutrients, and no luxury consumption, it appears that to produce 9 lb. of fruit per plant, nitrogen, phosphate and potash equivalent to some 3.8 oz of sulphate of ammonia, 2.1 oz of superphosphate, and 3.8 oz of muriate of potash per square yard should be available to the plant. It will be seen that the nitrogen supplied by the standard fertilizer is slightly less than the estimated uptake for a crop of this size. Two later experiments with considerably increased quantities of nitrogen showed an uptake equivalent to 4.05 and 4.06 oz of sulphate of ammonia per square yard on a 9 lb. of fruit per plant basis. Data from the 1949-50 experiment (Table II) indicate that the calcium taken up would be equivalent to that in 2.9 oz per square yard of superphosphate and the magnesium equivalent to 2.2 oz per square yard of Epsom salts. These figures do not include the plant nutrients

present in prunings, an amount which will vary with the size of the laterals.

In estimating the fertilizer requirements of the crop, allowance must be made for certain losses by leaching and fixation. Availability of the applied fertilizer to the plant will also depend on the efficiency of the root system, which in turn depends on moisture, aeration and freedom from disease. In addition, appreciable amounts of nutrients may be lost in the formation of unwanted lateral growth. Quantities larger than those estimated above as supplying the direct needs of the plant are therefore advisable. There are indications that mineral salts in the root environment may have other effects on the plant, particularly on the water uptake[2]. Until the action of different salts is better understood, the most suitable proportions and quantities of fertilizers for any particular cultural conditions may be difficult to assess. The results do indicate that in the standard fertilizer used for these experiments, the nitrogen and perhaps the potash could be increased, and that superphosphate may be excessive, even from the point of view of supplying calcium as well as phosphate to the plant. In soils less well supplied with magnesium, the use of magnesium fertilizers would appear essential.

The data in Table VI emphasize the importance of an adequate supply of available potash and nitrogen early in the season, particularly in the November-December period when the increase in weight of fruit is very rapid. It is possible that the drain on these elements for fruit development may be mainly responsible for the check in vegetative growth about this time, and that a more liberal supply, or more frequent topdressings may help to keep up production in the later part of the season. Excessive amounts of these fertilizers must be avoided, however, as they tend to reduce growth and yield, presumably owing to a high salt concentration in the soil.

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FIELD TRIALS OF FIVE SWEDE VARIETIES WITH SPECIAL REFERENCE TO APHID RESISTANCE

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Summary

In field trials carried out in Auckland and Ashburton, N.Z. Calder and N.Z. Sensation swedes supported significantly lower populations of cabbage aphid, *Brevicoryne brassicae* (L.), than N.Z. Grandmaster and N.Z. Superlative swedes. In an Auckland trial they outyielded the latter varieties and had a lower incidence of turnip-mosaic and soft-rot.

In a trial in South Canterbury, the variety N.Z. Resistant supported significantly lower populations of *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulz.) than Calder swedes and also produced larger roots. The proportion of alate : apterous aphids was considerably higher on N.Z. Resistant than on Calder plants.

Introduction

Each year approximately 2,000,000 acres are devoted to field crops in New Zealand (Anon., 1952). Of this area over one third is sown in the Brassicas: swedes, rape, turnips and kale. Three major insect pests viz. diamond-backed moth (*Plutella maculipennis* Curtis), white butterfly (*Pieris rapae* L.) and cabbage aphid (*Brevicoryne brassicae* (L.)) cause substantial annual losses of these crops. In early summer the grass grub (*Costelytra zealandica* (White)) is a serious pest in some areas. In addition to the direct damage done by these insects there may be secondary effects such as the invasion of soft rot bacteria following defoliation by aphids. Aphids are also of importance as vectors of turnip-mosaic virus.

As chemical control is not generally practised against these field-crop insects in New Zealand it is pertinent to consider alternative control methods such as the use of insect resistant plant varieties. It has been suggested that certain swede varieties might be resistant to cabbage aphid attack (Hudson, 1931; Wallace, 1946; Claridge, 1949). These reports have, however, been in general terms and unsupported by quantitative data. Palmer (1953) recently assessed a number of swede varieties for aphid damage and concluded that several varieties were aphid resistant.

The experiments reported in this paper were designed to obtain quantitive field evidence for the occurrence of aphid resistance in some swede varieties which are widely grown in New Zealand. The agronomic characters of the varieties tested (other than Calder) were summarized by Wallace (1946). Calder variety, described by Claridge (1949), was selected from progeny of a double hybrid between Sensation and Grandmaster swedes.

Experimental Procedure

One trial was carried out at the Plant Diseases Division, Auckland in 1949-50. Two further trials at Ashburton and Lowcliffe (South Canterbury) were carried out in 1951-52. The Auckland and Ashburton trials were laid out in randomized blocks and comprised the

swede varieties, N.Z. Calder, N.Z. Sensation, N.Z. Grandmaster and N.Z. Superlative. The Lowcliffe trial was laid out in alternate four-row plots of N.Z. Calder and N.Z. Resistant swedes.

The Auckland trial was sown in November, 1949, and 20 plants were sampled at random from each plot in February, August and December, 1950. Sample plants were pulled up and the root and top of each plant were weighed separately. In the August samples all aphids were washed from the leaves, collected in 10 per cent formalin and later counted.

A series of single-leaf counts of aphids were carried out *in situ* in April-June 1950. The third and sixth leaves from the centre were marked on each of 16 plants of each variety. The aphids on the marked leaves were counted at weekly intervals until the leaves died.

In August, field counts were made of plants showing turnip-mosaic symptoms. The presence of turnip-mosaic virus was confirmed by transmission to turnip and tobacco plants by leaf rubbing. In early September, the percentage of soft rot infected plants was determined and subjected to analysis of variance using the equivalent angle transformation.

The Ashburton trial, sown in November 1951, was sampled in February 1952 and again three weeks later. In the first set of samples, the tops of four plants taken at random from each plot were cut off, weighed, and the aphids present counted. The second set of sample plants were pulled up, roots and tops weighed separately, and the aphids washed off the leaves and preserved for counting.

The Lowcliffe trial was sown in October 1951 and sampled in March 1952. Plants were taken from four positions in each plot. Roots and tops were weighed and aphids collected as above. Apterous and alate aphids were counted separately and the counts subjected to analysis of variance using the log $(n + 1)$ transformation. The aphid samples were later re-examined and approximately fifty apterous aphids from each jar were classified into species. The results of the two counts were combined and the trial was re-analysed for three positions on a split-plot basis.

Results

(1) *Auckland trial*

The results of the August aphid counts are summarized in Table I.

Calder plants did not differ significantly from Sensation plants in number of aphids present, but both varieties had significantly fewer aphids present than Grandmaster or Superlative plants. The aphid density, expressed as log. (number of aphids/unit crown weight), was significantly higher on Superlative plants than on any other variety. *Brevicoryne brassicae* (L.) was the dominant aphid species though small numbers of other species, mainly *Myzus persicae* (Sulz.) and *Rhopalosiphum pseudobrassicae* (Davis) were also present. The figures in Table I refer to total numbers of aphids.

TABLE I. APHID COUNTS ON WHOLE SWEDE PLANTS
(Auckland, Aug. 1950).

Variety	Mean number of aphids per plant		Aphid density
	log (n+1)	equivalent number	
Calder	2.67	467	1.63
Sensation	2.64	436	1.72
Grandmaster	2.96	911	2.29
Superlative	2.82	660	3.11
Difference for 5%	0.13		0.69
Significance 1%	0.17		0.91

The results of the April-June single leaf counts are summarized in Fig. 1.

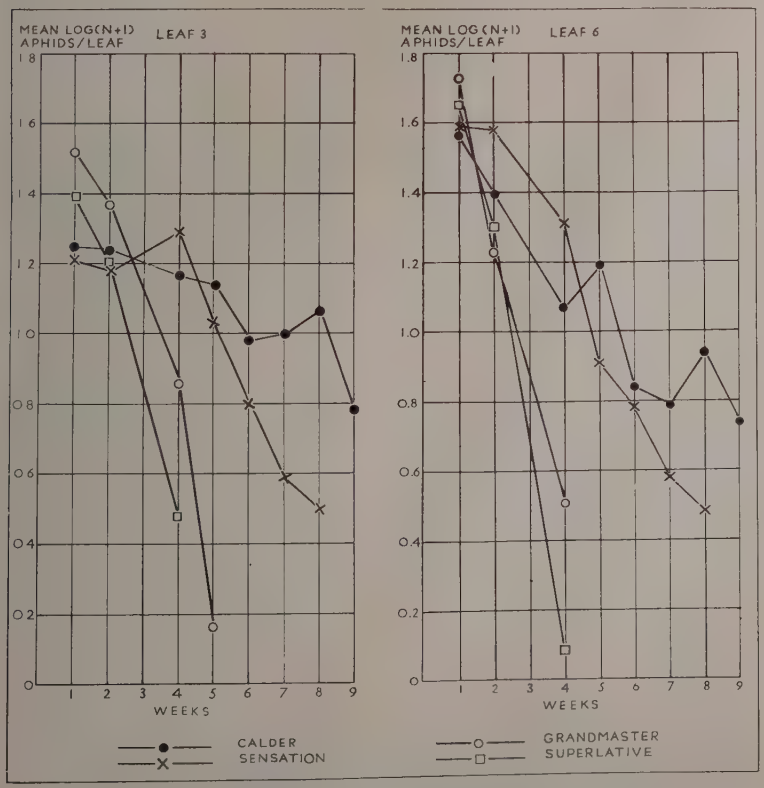

FIG. 1.—Single leaf aphid counts—Auckland (April-June 1950).
● = Calder; × = Sensation; O = Grandmaster; ■ = Superlative.

In this graph the difference between any two means required for significance is 0.29 ($P = 0.05$) or 0.38 ($P = 0.01$). These levels of significance refer to the means of 16 leaves and cannot be applied after five weeks as the number of living leaves decreased after the fifth week. Relatively few *B. brassicae* were present, the other two species being dominant in this series of counts. On Grandmaster and Superlative swedes the aphid population started at a higher level but decreased more rapidly than on Calder or Sensation swedes. The leaves of the latter two varieties lived longer. Within varieties, the aphid populations on the third and sixth leaves varied in a similar manner. Differences between varieties become more marked as the experiment proceeded. The earlier death of Grandmaster and Superlative leaves could be explained either as a result of damage from higher initial aphid populations or as a physiological characteristic

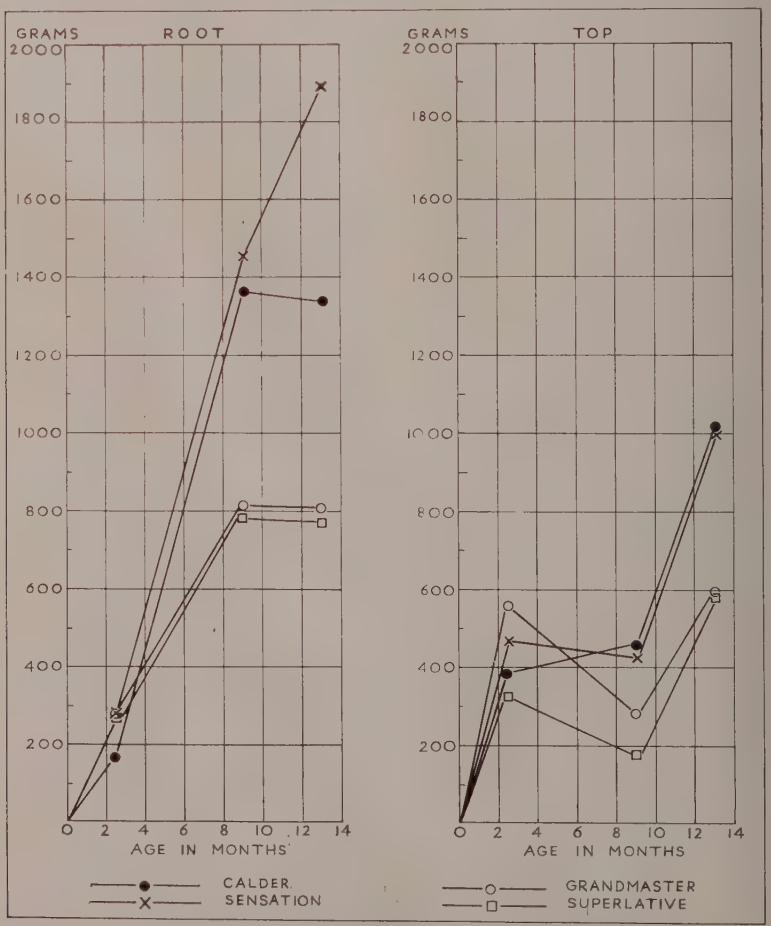

FIG. 2.—Swede plant weights—Auckland, 1950.

of the varieties concerned. As the aphid numbers per leaf were not large at the start of these counts, the latter explanation is probably correct. It is generally accepted that leaves have a definite physiological "life history." Thus, despite similarity of position on the plants, the leaves chosen at the commencement of this series of counts could well have been of different physiological ages in different varieties.

Examination of population trends on individual plants did not reveal any evidence of increase in aphid numbers with onset of leaf senescence (c.f. Kennedy *et al.*, 1950).

The mean plant weights at various times are shown graphically in Fig. 2.

The differences between root weights required for significance at nine months are 355g. ($P = 0.05$) or 469g. ($P = 0.01$) and between top weights: 79g. ($P = 0.05$) or 105g. ($P = 0.01$). Though there was no significant difference in weight between varieties at $2\frac{1}{2}$ months, at subsequent samplings, Calder and Sensation outyielded Grandmaster and Superlative varieties.

The relative difference in size between varieties was conspicuous in October during the flowering period (see Fig. 3).

FIG. 3.—Varieties in Auckland swede trial, October 1950: (a) Superlative, (b) Grandmaster, (c) Sensation, (d) Calder.
Photo: S. A. Rumsey

In August, all Grandmaster and Superlative plants showed symptoms of turnip-mosaic but only 12 per cent of the Calder and 15 per cent of the Sensation plants showed symptoms. This confirms the observation by Chamberlain (1949) that Calder (= Dryland) and Sensation swedes show considerable resistance to turnip mosaic virus.

The percentage of soft-rot infected plants in September is shown in Table II. Calder and Sensation plants showed much less infection than Grandmaster or Superlative plants.

TABLE II. PER CENT SOFT-ROT INFECTED SWEDES
(Auckland, Sept. 1950).

Variety	Equivalent angle	Pecentage infected
Calder	5.23	0.8
Sensation	8.38	2.1
Grandmaster	34.66	32.3
Superlative	37.21	36.6
Difference for 5%	4.36	
Significance 1%	5.91	

(2) *Ashburton trial*

When this trial was first sampled conditions were very dry and infestation with *Brevicoryne brassicae* was heavy. The plots of Calder and Sensation plants could readily be distinguished by their more robust appearance. This difference was even more marked at the second sampling, when many of the Grandmaster and Superlative leaves were dead or dying.

Mean aphid counts for both sets of samples are given in Table III.

TABLE III. SUMMARY OF APHID COUNTS
(Ashburton, 1952).

Variety	Mean number of aphids per plant			
	February sample		March sample	
	log (n+1)	equivalent number	log (n+1)	equivalent number
Calder	1.81	64	2.59	388
Sensation	2.27	185	1.82	65
Grandmaster	3.24	1737	2.85	707
Superlative	3.05	1121	2.07	117
Difference for 5%	0.52		0.50	
Significance 1%	0.78		0.73	

The relatively lower counts on Grandmaster and Superlative plants in the second samples were due to the death of leaves referred to above.

There was no significant difference in root or top weights between varieties (Table IV).

(3) *Lowcliffe trial*

The total counts of alate and apterous aphids, irrespective of species, are summarized in Table V. The proportion of alates to apterae was considerably higher on N.Z. Resistant variety. This suggests that this variety was a less satisfactory host than was Calder.

TABLE IV. MEAN PLANT WEIGHTS
(Ashburton and Lowcliffe trials).

Variety	Ashburton Trial		Lowcliffe Trial	
	Mean top Wgt. (g)	Mean root Wgt. (g)	Mean top Wgt. (g)	Mean root Wgt. (g)
Resistant			551	1582
Calder	201	140	659	1148
Sensation	247	229		
Grandmaster	110	89		
Superlative	113	123		
Difference for 5%	not significant		not significant	341
Significance 1%				479

TABLE V. SUMMARY OF TOTAL APHID COUNTS, IRRESPECTIVE OF SPECIES
(Lowcliffe, 1952)

Variety	Mean number of apterae per plant		Mean number of alatae per plant	
	log (n+1)	Equivalent number	log (n+1)	Equivalent number
Calder	3.34	2187	1.23	16
Sensation	2.24	174	0.98	9
Difference for 5%	0.40		0.20	
Significance 1%	0.66		0.28	

The split-plot analysis of the counts of apterae with species separated is summarized below and the sampling data are given in Table VI.

These results show a marked varietal difference between Calder and N.Z. Resistant in aphid populations, but absence of interaction between plant varieties and aphid species suggests that N.Z. Resistant swedes are equally resistant to *Brevicoryne brassicae* and *Myzus persicae*. Both aphid species were abundant, but *B. brassicae* occurred in larger numbers than did *M. persicae*. The means for blocks and

TABLE VI. APHID SAMPLING DATA
(Lowcliffe trial)

Block V		Block IV		Block III		Block II		Block I		Aphid species	Sample position
Resist.	Calder	Resist.	Calder	Resist.	Calder	Resist.	Calder	Resist.	Calder		
31	6135	53	789	108	2052	87	475	33	261	B. brassicae	1
46	1731	8	1090	45	741	94	1108	17	94	M. persicae	
85	5636	165	1017	173	888	77	1081	53	358	B. brassicae	2
55	4082	178	1017	19	545	40	627	21	1019	M. persicae	
83	3750	169	4018	116	1290	58	663	53	362	B. brassicae	3
167	962	348	2463	46	1290	28	373	63	480	M. persicae	

TABLE VII. ANALYSIS OF LOWCLIFFE APTEROUS APHID COUNTS ON SUB-SUB PLOT BASIS

	s.s.	d.f.	m.s.	F.	Significance
Whole plots:					
Between blocks	2.770	4	0.693		N.S.
Swede varieties	21.949	1	21.949	103.05	1%
Error (a)	0.851	4	0.213		
Sub plots:					
Between positions	0.500	2	0.250		N.S.
Positions × varieties	0.103	2	0.051		N.S.
Error (b)	2.194	16	0.137		
Sub-sub plots:					
Between aphid species	0.411	1	0.411	4.67	5%
Species × varieties	0.019	1	0.019		N.S.
Species × positions	0.041	2	0.020		N.S.
Species × positions × varieties	0.162	2	0.081		N.S.
Error (c)	1.405	16	0.088		
Total	30.405	51			

TABLES OF MEANS

Blocks	1	2	3	4	5
Log (n+1)	2.05	2.44	2.54	2.57	2.53
Equivalent number	112	275	345	370	660

Varieties	N.Z. Resistant	Calder
Log (n+1)	1.88	3.04
Equivalent number	75	1080

Positions	1	2	3
Log (n+1)	2.32	2.50	2.59
Equivalent number	207	315	384

Species	B. brassicae	M. persicae
Log (n+1)	2.55	2.39
Equivalent number	350	242
Percentage	58	42

sampling positions indicated the general form and density of aphid infestation over the trial area. Smaller aphid populations were found on N.Z. Resistant plants than on Calder plants.

Mean plant weights are given in Table IV. There was no significant difference in top weight but root weight was significantly higher in N.Z. Resistant than in Calder.

Discussion

The above results indicate that Calder, Sensation and Resistant swedes are characterised by vigorous growth habit and support lower aphid populations than Grandmaster or Superlative varieties. From the results of the Lowcliffe trial it appears that *Myzus persicae* populations behave in a similar manner to *Brevicoryne brassicae* populations —at least on Calder and Resistant varieties, e.g., Resistant variety supported smaller populations of both species of aphids than did Calder variety.

Calder and Sensation swedes also appear to be resistant to turnip mosaic virus and soft-rot. This resistance to virus infection is of particular interest in view of the observations of Kennedy (1951) who found that *Aphis fabae* Scop. reproduced more rapidly on virus infected than on healthy sugar beet plants.

The single-leaf counts of aphids carried out in the Auckland trial are of interest. It is not an uncommon practice to take single leaf counts as a measure of insect population level. However, since the physiological age of leaves in similar positions may vary from one variety to another, as was probably the case in the above trial, the results of such counts should be interpreted with caution. Unless some allowance is made for variable physiological leaf age it would seem more desirable to take total aphis counts on all leaves of each plant.

Climatic conditions appear to be of considerable importance in determining habit and relative growth rates of different varieties. Aphid resistance appears to vary in degree in different localities and may possibly be correlated to some extent with growth rate.

It is noteworthy that Calder and Sensation swedes, although originally introduced as varieties suitable for drier areas, will produce relatively higher yields than Grandmaster and Superlative swedes even in wetter districts. The varietal difference in yield may indeed be very marked under such conditions, e.g., in the Auckland trial.

Experiments reported in this paper indicate that aphid resistance exists in Calder, Sensation and Resistant swede varieties. It has been demonstrated to occur in the first two varieties in different seasons and localities and may be presumed to be genetic in nature. Since Sensation is the only parent variety of Calder known to exhibit aphid and virus resistance, it would seem that these characters have been inherited in Calder from Sensation. The variation observed in degree of resistance from place to place or season to season is consistent with the modifying effects of environment on the expression of a genetic character.

The cause of aphid resistance in swedes is not known. It may be due to one or more factors. The occurrence of aphid resistance together with virus resistance in Calder and Sensation is suggestive, but much further work will be required to elucidate the nature of aphid resistance.

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USE OF METHYL BROMIDE FOR THE CONTROL OF WEEDS IN TOBACCO SEEDLING BEDS

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Summary

Methyl bromide gas at the rate of 1 lb. per 100 sq. ft. of bed area proved equally as effective as steam in controlling weeds and stimulating growth of tobacco in seedling beds. There were no toxic after effects.

Introduction

For the tobacco grower who sets out to raise his own seedlings, weeds in the seedling bed present the greatest problem. Sowing extends from late August to mid-September. Under extremely favourable conditions seed may germinate in fourteen days, but three weeks is the average period and four weeks is not uncommon. The seedlings are very small, and early growth is slow, whereas weeds at that time are very aggressive; they germinate ahead of the tobacco and grow much more rapidly, soon smothering the tobacco seedlings. Weed seeds can be effectively controlled, however, by previously steam sterilising the soil, but facilities for steaming are limited, and the high cost of equipment, together with the short period for which it is in use makes it unlikely that any additional plant will become available. There was a period, during the general change over from the steam engine to the internal combustion engine, when discarded steam boilers in good working order were fairly readily obtainable. These boilers have now reached the end of their useful life and the need for a satisfactory alternative method of sterilising becomes more urgent. Experiments to find such a method have been carried out over a number of years with varying success; these have been reported in a previous paper[1]. More recently, trials have been carried out with methyl bromide gas, which requires much less equipment and appears reasonable in cost. This treatment would be particularly useful in the more remote areas where there is no possibility of securing facilities for steaming.

The problem is by no means confined to New Zealand, but exists wherever tobacco is grown. Of the various chemicals tried overseas, methyl bromide has given promising results. Hill and co-workers[2] reported excellent control of a large number of weed species in tobacco beds on sandy loams. Koch[3] in preliminary trials found that methyl bromide gave good control of weeds other than mallow and clover, stimulated the growth of seedlings, and controlled soil-borne diseases. Kopitke[4] stated that methyl bromide treatment of nursery land provides a complete, non-selective weed control without leaving any harmful residue in the soil. Anderson and Swanbeck[5] ranked methyl bromide slightly superior to steam in weed control and growth stimulation.

Experimental Procedure

The trials were carried out under field conditions in ordinary seedling beds, 24 ft. long by 4 ft. wide. To ensure a representative popula-

tion of weed seeds the beds were dug out each year to a depth of 5–6 in. and filled with new soil obtained from round the fence lines. The soil was a sandy loam in good physical condition and well supplied with organic matter. The beds all received the same cultural treatment. Fertilizer was applied after sterilizing and a week before sowing at ¾ lb. per sq. yd. Beds were seeded direct at the same time as commercial sowings, viz. early September, and were then covered with tobacco calico and watered in the usual way. Each bed was divided into three sections, with a steamed and an unsteamed section in each for comparison. Treatments were replicated in three beds.

Methyl bromide at low temperature or under pressure is an odourless, clear liquid, but at temperatures above 43° F it quickly vaporises and the vapour disperses rapidly and has remarkable penetrating powers. In the seasons 1950 and 1951, it was obtained in 1-lb. canisters. With these was provided a special applicator, which, when clamped on to the canister, punctured the tin and allowed the methyl bromide to flow out through a plastic delivery tube. For the 1952 season, the 1-lb. canisters were no longer available and the material was obtained in 140-lb. cylinders. To measure the dosage, the cylinder was mounted on a platform scale (Fig. 1) and the amount determined by loss in weight.

The beds were prepared by deep forking, breaking down all lumps, and then raking level. To contain the gas it was necessary to enclose the beds in a gas-tight cover. In the first two seasons, a polythene plastic sheet 0.01 in. thick was used, and in the third season "Sisalkraft" building paper. A wire was stretched down the centre of the bed about six inches above the ground to provide a central support, and the cover

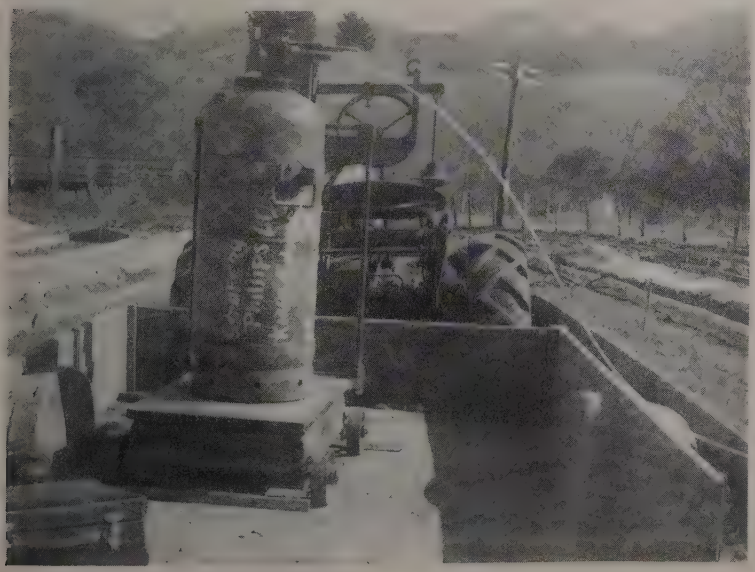

FIG. 1.—140-lb. Cylinder of Methyl Bromide in Position on Platform Scales.

was pulled tight over it. The edges of the cover were made gas tight by pressing them on to the ground and shovelling a 4-in. layer of soil over them. Before the cover was actually sealed a delivery tube was placed in position.

When the 1-lb. canisters were used, the methyl bromide was liberated in liquid form, so the end of the tube was placed in a shallow tray on the surface of the soil. This collected the liquid and allowed it to evaporate under the cover. The 140-lb. cylinders had both gas and liquid outlets, but only the gas outlet was used, so that no tray was needed under the cover. The rate of application was 1 lb. per 100 sq. ft. of bed area in all cases. As soon as the required quantity of methyl blomide had been delivered, the tube was withdrawn and the opening sealed off by firming down with the foot.

Fig. 2.—Alternate Beds Covered with "Sisalkraft" Building Paper ready for Treatment.

Trials were carried out under a wide range of soil temperatures, the lowest being in 1951 when the readings after a cold night were 39.5°F at 3 in. depth and 41° F at 6 in. The highest temperatures were in 1950 when the corresponding readings were 55° F and 50° F respectively. The covers were left in place for 72 hours, after which fertilizer was applied broadcast by hand and worked in with a rake. Seed was sown later, the time of sowing varying from one day to three weeks after the removal of the cover.

Results

Two weed counts were made, the first six weeks after sowing, and the second three weeks later. At each count the weeds were removed from the beds. Results are given in Table I.

TABLE I. EFFECT OF METHYL BROMIDE ON THE GROWTH OF WEEDS

Treatment	Weeds per sq. ft. of bed			
	1950	1951	1952	Average
Steam	9.3	1.0	0.3	3.5
Methyl bromide	5.9	0.4	0.4	2.2
Control, untreated	123.4	169.0	34.4	108.9

A study of the Table shows that methyl bromide has controlled the weeds as effectively as has steam. In each trial the untreated controls were very weedy (Fig. 3), the predominating species being: black nightshade (*Solanum nigrum*), shepherds purse (*Capsella bursa-pastoris*), redshank (*Polygonum persicaria*), spurrey (*Spergula arvensis*), fathen (*Chenopodium album*), chickweed (*Cerastrium arvense*), catsear (*Hypochaeris radicata*), docks (*Rumex* spp.) and annual poa (*Poa annua*). The removal of the weeds greatly depleted the stand of tobacco, by the unavoidable lifting of the tobacco seedlings at the same time. Growth of the tobacco seedlings in the methyl bromide plots was equal to that in the steam-sterilized sections. Both treatments stimulated the germination of hard seeded legumes such as white clover, gorse and tree lucerne, but these were so few that they

FIG. 3.—Effect of Methyl Bromide on Weeds; foreground treated, background untreated.

were easily pulled by hand. Despite the great variation in soil temperatures, and the fact that the lowest figure is about ten degrees below the minimum recommended, the results achieved were uniformly satisfactory.

Field Trials

Following the success obtained with the Station trials in 1950 and 1951, it was decided to supplement them in 1952 by larger trials on growers' properties, so that information could be obtained on the effectiveness of the method on a variety of soil types, and under varying conditions.

Eight growers co-operated. The soils varied from a heavy silt of Moutere origin to an open granite sand, and a wide range of farm conditions was encountered. For the trials a length of bed 50 ft. long by 4 ft. wide was used, except in one instance where beds 150 ft. long were treated. "Sisalkraft" building paper was used for covers. The delivery tube was placed at the centre point of the 50 ft. length, and 2 lb. of methyl bromide released in one application. In the 150-ft. bed, tubes were inserted 25 ft. from each end, and the others at 50 ft. intervals. In some cases the fertilizer had already been applied before treatment. Covers were left in place for times ranging from 48 to 72 hours, although in one instance a strong wind blew the cover off the bed 30 hours after treatment. In many trials seed was sown the day after removing the cover.

In all cases excellent control of weeds was obtained. The variety of soils and locations provided a wide range of weed species, the more aggressive ones noted in the untreated portions of the beds being couch grass (*Agropyron repens*), dock (*Rumex*, spp.), yarrow (*Achillea millifolium*), sorrel (*Rumex acetosella*), spurrey (*Spergula arvensis*), fathen (*Chenopodium album*), and black nightshade (*Solanum nigrum*). There were no toxic after effects from the treatments. Even where sown immediately after the removal of the covers the tobacco germinated well and came away rapidly, in all cases much ahead of the untreated sections.

Discussion

Methyl bromide has definitely proved the equal of steam in controlling weeds in tobacco seedling beds. The 1-lb. canisters provide the simplest form of application, but if these are not available large cylinders may be used. The dosage from cylinders may be measured quite satisfactorily on a platform scale by noting the loss in weight as the gas is released. Either plastic or "Sisalkraft" covers may be used. At the time of commencing these trials, the only plastic sheeting available was 0.01-in. polythene. This is unnecessarily heavy and a much lighter weight would be quite satisfactory. Information received since commencing the trials has indicated that polyvinyl-chloride plastic is also quite suitable. Plastic is easier to handle and would have a longer life than the building paper. Furthermore the latter is obtainable in a maximum width of 5 ft. and this is really too narrow to cover a 4-ft. bed satisfactorily. Two pounds of gas delivered at intervals of 50 ft. gives satisfactory coverage in the standard 4 ft. wide bed. No adverse effects were noted when the fertilizer had been incorporated

in the soil prior to treatment. While it is desirable to leave the covers in place for a period of from 48 to 72 hours, the fact that excellent results were obtained where the cover was blown off 30 hours after treatment suggests that under favourable weather conditions the recommended period may be shortened.

Because methyl bromide is a highly poisonous substance and is colourless and odourless it is dangerous to handle[6]. It can be obtained containing 2 per cent chloropicrin as a lachrymator indicator, and this mixture should always be used. If it is handled entirely in the open air, and the operator stands on the windward side of the apparatus and remains upright all the time there should be no undue risks as the gas is heavier than air.

The above trials have been concerned entirely with the control of weeds in seedling beds. There have been indications that methyl bromide also has possibilities for the control of fungous diseases in the soil. Dr. K. M. Curtis, of the Cawthron Institute, carrying out a complementary series of trials over the same period, found that methyl bromide at the rate of 1 lb. per 100 sq. ft. gave excellent control of black root-rot (*Thielaviopsis basicola*) in tobacco seedling beds (Pers. comm.).

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EFFECTS OF DELAY BETWEEN HARVESTING AND COOL-STORING ON STURMER PIPPIN APPLES

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Summary

Sturmer Pippin apples from six different orchards in the Hastings area were subjected to varying delays between picking and storing in cool-chambers. As the length of delay before storing increased, quality of the fruit on removal from store decreased. Quality was lowered by a falling-off in hardness and by a sharp rise in the incidence of storage disorders. Bruise incidence was not reduced by pre-storage delay, but bruise appearance was altered.

It is concluded that Sturmer apples should be placed in cool-store as soon as possible after picking.

Introduction

There is a popular belief among orchardists that Sturmer Pippin apples must be withheld from cool-storage for 10 days after picking. The Sturmer variety bruises easily, and it is claimed that this treatment allows the harvesting bruises to disappear. Owing to labour shortages and insufficient cool-storage facilities, the fruit from many orchards is often held for periods considerably in excess of 10 days before being placed in cool-store.

Heavy losses due to physiological disorders and fungous rots are often experienced with the variety in cool-store. As delayed cool-storage adversely affects keeping quality in many apple varieties, it seemed probable that much of this loss could be avoided if the apples were placed in store promptly.

To test the effect of delayed storage on bruise appearance and keeping quality, the following work was undertaken.

Materials and Methods

Fruit was taken from two orchards in each of three localities representative of the main Hastings fruitgrowing area. In previous years one orchard from each locality had produced fruit of good keeping quality, while fruit from the other had not kept well.

Orchards 2 and 5 were situated in Twyford on Twyford sandy loam (Hughes, Hodgson and Harris, 1939). Numbers 1 and 6 were situated in St. George's Road, No. 1 on Twyford sandy loam and No. 6 on Pakowhai clay loam. Orchards 3 and 4 were in the Havelock North area, and both included soils from the Hastings and Twyford series. Fruit was picked during April in each of the two years, picking dates being spread over 17 days in 1951 and 14 days in 1952.

In both 1951 and 1952, 15 bushel cases were taken from the main commercial picks of each orchard. These were to be stored in 5-case groups, which were to be placed successively in cool-storage,

TABLE I. FRUIT COUNTS PER SAMPLE, PRE-STORAGE DELAY, TIMES FROM HARVEST TO EXAMINATION AND MEAN BRUISE COUNTS PER STURMER APPLE PRIOR TO STORAGE

ORCHARD	TREATMENT	1951				1952			
		No. of fruits per sample	No. of days between harvest and storage	No. of days from harvest to examination	No. of bruises per apple	No. of fruits per sample	No. of days between harvest and storage	No. of days from harvest to examination	No. of bruises per apple
1	1	526	1	103	8.0	600	5	100	19.2
	2	538	11		3.9	600	12		18.2
	3	551	21		7.9	584	19		19.1
2	1	600	4	167	6.2	600	1	173	25.7
	2	600	14		3.8	600	11		15.4
	3	600	24		7.9	600	21		15.3
3	1	600	1	104	12.6	600	1	111	15.6
	2	600	11		6.0	600	11		12.4
	3.	600	21		5.8	600	21		9.7
4	1	552	2	155	7.2	451	1	140	17.2
	2	552	11		2.8	589	11		13.7
	3	552	22		2.7	589	21		14.1
5	1	600	2	167	14.8	300	1	141	18.6
	2	600	12		6.4	300	12		14.8
	3	600	21		12.4	300	20		17.4
6	1	564	1	158	13.7	614	0	143	19.0
	2	589	11		13.1	639	13		18.0
	3	589	21		14.5	651	20		17.6

immediately after harvest, and after delays of 10 and 20 days from harvest. Of each group of 5 cases, one was used as a pilot case, while the other 4 constituted the sample proper. In order to have comparable samples it had been the intention that all boxes should contain 150 apples.

Table I shows that both counts and delay periods varied slightly from these theoretical conditions. There was one large variation in 1952 when only two-bushel samples were examined from Orchard 5. This reduction in sample size became necessary because the remainder of the consignment was severely damaged while en route to the cool-store. The fruit was held in a commercial cool-store at 34°F.

Hardness

Fifty apples from the pilot case were measured for hardness with a penetrometer fitted with a $\frac{7}{16}$-in. plunger. These measurements were made immediately before each sample was placed in cool-store. Additional measurements on a further 50 apples from the same box were made immediately after each sample was removed from storage.

Bruising

Bruises were counted on 25 apples from the middle layer of each pilot case just prior to storage.

Storage Periods and Examinations

Because Sturmers are considered to be a long-term, cool-storage variety, it was asumed that every sample would remain in perfect condition for at least 100 days; therefore, no examinations were made until this period had elapsed. Samples from any one orchard were examined (Table I) when fruit in the pilot cases showed some internal-breakdown. Unfortunately, some examinations had to be delayed, particularly in 1951, and this is probably responsible for the rather high percentage of breakdown sometimes encountered.

All the fruit was examined externally and internally immediately it was removed from storage. Examination of the three samples from each orchard took place over a period covering two to three days.

Results

A preliminary account of the results obtained in the first season has already been published (Padfield, 1952).

Bruising

Table I presents the average bruise counts per apple immediately prior to storage. The erratic numbers from the three samples from some orchards, suggests that certain individual cases received harsher treatment than others.

There was little indication that bruises disappear within 20 days of harvest. The appearance of bruises changed from the early, unsightly, water-soaked, brown appearance to the later,

TABLE II. PERCENTAGES OF SOUND STURMER APPLES REMAINING AFTER STORAGE

1951

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	86	73	69	78	43	43	63
2	52	41	41	55	44	50	47
3	42	17	40	27	34	39	33
Orchard mean	60	44	45	53	40	44	

Conversion to equivalent angles:

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	68.10	59.24	56.25	61.14	40.75	40.98	54.41
2	46.02	39.63	39.63	47.76	41.31	45.27	43.26
3	40.51	24.10	39.47	31.32	35.20	38.92	34.92
Orchard mean	51.54	40.98	45.11	46.74	39.08	41.72	

Differences required for significance:		5%	1%
	Between treatment means over all orchards	9.76	13.88
	Between treatment means within orchards	6.80	9.15
	Between orchard means	15.46	21.99

1952

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	57	89	96	86	80	84	82
2	33	60	95	61	60	77	64
3	38	23	76	41	41	57	46
Orchard mean	43	57	89	63	60	73	

Conversion to equivalent angles:

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	48.88	70.20	79.15	68.23	63.80	70.07	66.93
2	34.75	50.65	78.75	50.85	51.10	61.88	54.99
3	37.45	28.25	61.73	39.28	39.80	49.15	42.86
Orchard mean	40.36	49.70	73.21	51.38	51.57	60.36	

Differences required for significance:		5%	1%
	Between treatment means over all orchards	4.15	5.54.
	Between treatment means within orchards		
	(a) All orchards except No.5	10.38	13.85
	(b) Orchard No.5	13.60	18.14
	Between orchard means	6.90	9.20

less noticeable, dry indentation. In most cases it was observed that this change was not completed within 10 days and sometimes not within 20 days. After storage, all apples showed bruises as dry indentations.

There was no indication that damage was bad enough to induce bruise-breakdown in any sample.

Sound fruit

Table II gives the percentages of sound fruit remaining after

TABLE III. PERCENTAGES OF STURMER APPLES SHOWING INTERNAL-BREAKDOWN AFTER STORAGE

1951

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	12	19	25	20	55	47	30
2	42	49	53	40	44	32	43
3	39	71	45	67	61	35	53
Orchard mean	31	46	41	42	53	38	

Conversion to equivalent angles:

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	19.78	25.25	30.12	26.03	47.64	41.59	31.73
2	40.90	44.18	46.65	38.95	41.62	31.58	40.65
3	38.63	57.88	42.42	55.01	51.76	34.13	46.64
Orchard mean	33.10	42.44	39.73	40.00	47.00	35.77	

Differences required for significance:		5%	1%
	Between treatment means over all orchards	11.55	16.43
	Between treatment means within orchards	12.00	16.13
	Between orchard means	18.63	25.50

1952

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	43	9	4	14	13	14	16
2	67	33	5	40	37	20	34
3	62	51	18	58	53	27	45
Orchard mean	57	31	9	37	34	20	

Conversion to equivalent angles:

Treatment	ORCHARD						Treatment mean
	1	2	3	4	5	6	
1	40.75	16.92	10.68	21.97	21.39	19.31	21.87
2	54.86	34.46	13.85	38.98	37.28	26.03	34.92
3	51.95	45.13	24.29	49.99	46.55	30.28	40.89
Orchard mean	49.19	32.17	16.49	38.34	35.07	25.21	

Differences required for significance:		5%	1%
	Between treatment means over all orchards	4.88	6.50
	Between treatment means within orchards		
	(a) All orchards except No. 5	12.07	16.10
	(b) Orchard No. 5	15.80	21.07
	Between orchard means	7.90	10.54

storage. Results show that percentage of sound fruit is reduced by pre-storage delay.

Internal-breakdown

This disorder was the main cause of loss from all orchards. Results in Table III show that it increased as the delay between harvest and storage was prolonged. Breakdown in fruits from Orchards 1 and 3 occurred in less than 100 days in both years. Thus the Sturmer apple cannot always be considered a long-term storage variety and, for reasons outside the scope of this study, some orchards produce fruit of poor keeping quality.

TABLE IV. HARDNESS OF FLESH OF STURMER APPLES (IN LB. PRESSURE) PRIOR TO COOL STORAGE AND ON REMOVAL FROM STORE

		1951		1952	
Orchard	Treatment	At storage	On removal	At storage	On removal
1	1	12.5	9.8	9.8	7.8
	2	10.0	8.5	9.7	6.6
	3	8.1	8.1	9.4	5.3
2	1	11.3	8.4	11.0	7.2
	2	9.7	7.4	9.8	6.2
	3	8.1	6.0	9.6	5.8
3	1	12.7	9.8	11.2	8.9
	2	9.6	8.7	9.7	8.8
	3	8.2	7.1	9.7	7.6
4	1	11.4	8.9	9.8	7.3
	2	9.2	7.6	9.1	6.0
	3	7.3	6.6	8.9	5.4
5	1	10.7	7.1	11.3	6.6
	2	8.9	6.4	10.4	6.2
	3	5.7	5.2	9.6	5.4
6	1	8.8	7.4	10.0	6.7
	2	6.9	6.7	10.1	6.0
	3	6.0	5.9	9.8	5.3

Wilt

Wilt occurred only in 1951, increased delay tending to cause increased wilting.

Superficial-scald

This disorder was worse in 1952 and was confined to certain orchards. Where it occurred, the disorder appeared to be aggravated by delay.

Core-flush

Only odd apples in most samples developed core-flush.

Ripe-spot (*Neofabraea malicorticis* (Cord.) Jack)

In 1951 fruit from two orchards, No. 3 and 6, developed ripe-spot. On both lots, the infection appeared to increase according to length of pre-storage delay.

Other disorders

A few apples in several samples showed signs of bitter-pit and fungous rots, but these could not be correlated with delay.

Hardness

Softening of the flesh of the fruit is often regarded as a measure of ripening rate and of senescence. Table IV shows that delayed

storage decreased hardness of fruit from all orchards. It is interesting to note that in 1951 apples which received the minimum storage delay were harder after storage than apples, delayed 20 days or more, were before storage.

Conclusions

The results indicate that delay before cool-storage does not reduce the incidence of bruising but does increase loss from storage disorders. Sturmer apples should therefore be cool-stored as soon as possible after being picked.

Acknowledgments

The statistical analyses were done by G. C. Ward and W. B. Taylor, of the Applied Mathematics Laboratory, Department of Scientific and Industrial Research.

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SEED DISINFECTION

VIII. CONTROL OF WEEVIL DAMAGING FRENCH BEANS AND MAIZE SEED IN STORAGE

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Summary

Proprietary seed dusts, viz. Spergon, Spergon DDT, Agrosan, and Agrosan BHC, were tested for control of the common bean weevil (*Acanthoscelides obtectus* Say.) and the rice weevil (*Calandra oryzae* L.).

Applications of combined fungicidal and insecticidal dusts reduced spread of bean weevil in an infected sample of French beans, the mixture containing BHC being more effective than that containing DDT.

Preventive treatment of French bean seed with fungicides with and without addition of insecticides materially reduced loss from weevil infestation.

Although Spergon alone gave some protection to maize seed against rice weevil infestation, the addition of DDT gave significantly better results. Agrosan by itself was not effective, but Agrosan with BHC gave results of the same order as those from Spergon DDT.

Pea seed was not attacked by either species of weevil.

Introduction

The common bean weevil (*Acanthoscelides obtectus* Say.) and the rice weevil (*Calandra oryzae* L.) cause considerable damage to bean and maize seeds stored in New Zealand. Tests were carried out to investigate the effect of proprietary seed dusts in control of these insects.

Materials and Methods

The following materials were used:—

French beans of the variety Canadian Wonder (approx. 1,000 seeds per lb); maize of the variety Pfister 360 (approx. 1,550 seeds per lb); and pea seed of the variety Greenfeast (approx. 1,900 seeds per lb).

The following dust treatments were applied at 0.2 per cent of seed weight:—

Spergon (98 per cent tetrachloro para benzoquinone);

Spergon DDT (93 per cent tetrachloro para benzoquinone plus 3 per cent dichloro diphenyl trichloroethane);

Agrosan (1 per cent tolyl mercury acetate);

Agrosan BHC (1 per cent tolyl mercury acetate plus 20 per cent benzene hexachloride (mixed isomers);

Talc.

Seeds and dusts were shaken for 5 min. in a rotary machine turning at 38 r.p.m.

After treatment, one pound samples of seeds were placed in quart jars with screw lids into which were fitted gauze discs. Five replica-

tions were used for each treatment. Jars were held at temperatures of 16° to 20°C.

Naturally infected seed was used in Experiment 1. In other experiments a number of adult weevils taken from infected seed were added to each jar 24 hours after seed treatment. Sixty-five weevils per jar were used in Experiment 2, and 25 weevils per jar in Experiments 3 and 4.

Sowings were made in unsterilized soil (35 to 45 per cent water-holding capacity) in a glasshouse (temperatures 22 ± 5°C), there being 5 replications of 50 seeds for each treatment. Sowings were made 1 day after seed treatment and at intervals of 3 months thereafter, and emergence was recorded 3-to-4 weeks after each sowing.

Results

Experiment 1: French bean

A sample containing a number of seeds damaged by the common bean weevil (Fig. 1) was used in this test. Results are given in Table I.

Fig. 1.—Beans injured by the common bean weevil (*A. obtectus* Say).
Photo: W. E. Barnard

Weevil infestation completely inhibited emergence in check samples after nine months storage. Spergon and Agrosan used alone did not reduce damage significantly. Agrosan BHC gave good protection and was significantly better than Spergon DDT.

Experiment 2: French bean

Sixty-five weevils were added to each replicate after seed treatment. Results are given in Table II.

TABLE I. EFFECT OF SEED TREATMENT ON EMERGENCE OF FRENCH BEANS NATURALLY INFESTED WITH COMMON BEAN WEEVIL

TREATMENT	Emergence after storage for: 1 Day		3 Months		6 Months		9 Months		12 Months	
	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle
Spergon	89.8	71.3	84.0	53.2	28.6	31.0	4.9	12.7	0.0	0.0
Spergon DDT.	81.6	64.6	82.5	40.8	53.[illegible]	47.[illegible]	72.5	28.4	11.7	20.1
Agrosan	80.5	64.0	47.8	43.7	39.3	39.[illegible]	0.0	0.0	0.0	0.0
Agrosan BHC	85.2	67.5	69.3	56.8	56.[illegible]	[illegible]	51.3	51.7	11.0	11.4
Talc	77.1	61.4	61.1	53.1	26.[illegible]	26.3	0.0	0.0	0.0	0.0
Difference required for significance at 5%	-	7.7	-	8.6	-	11.4	-	15.4	-	15.8

TABLE I. EFFECT OF SEED TREATMENTS ON EMERGENCE OF FRENCH BEANS ARTIFICIALLY INFESTED WITH COMMON BEAN WEEVIL

TREATMENT	Emergence after storage for: 1 Day		3 Months		6 Months		9 Months		12 Months	
	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle
Spergon	91.5	73.1	82.5	65.3	87.8	69.2	53.6	46.9	40.2	39.3
Spergon DDT	91.5	73.0	92.9	74.5	93.4	75.3	63.0	52.4	53.5	47.0
Agrosan	93.6	75.2	92.5	74.0	94.8	77.0	63.0	52.5	51.5	45.9
Agrosan BHC	94.8	76.4	92.9	74.5	95.0	77.0	70.8	57.0	59.3	50.5
Talc	82.0	64.7	63.9	53.0	0.0	0.0	0.0	0.0	0.0	0.0
Difference required for significance at 5%	-	8.7	-	12.1	-	17.6	-	14.8	-	13.8

Spergon and Agrosan with and without addition of insecticides significantly increased emergence. Although Spergon DDT gave better emergence figures than Spergon alone, none of the differences between treatments, other than checks, were significant.

Experiment 3: Maize

Twenty-five rice weevils were added to each replicate after seed was treated. Results are given in Table III.

TABLE III. EFFECT OF SEED TREATMENTS ON EMERGENCE OF MAIZE ARTIFICIALLY INFESTED WITH RICE WEEVIL

TREATMENT	Emergence after storage for:							
	1 Day		3 Months		6 Months		9 Months	
	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle	Percentage	Equivalent angle
Spergon	90.0	71.8	77.8	61.6	42.5	40.6	23.4	29.0
Spergon DDT	98.5	82.0	100.0	90.0	95.0	77.0	93.8	75.2
Agrosan	97.5	81.1	80.7	64.1	0.0	0.0	0.0	0.0
Agrosan BHC	97.5	80.0	85.0	67.3	85.0	67.3	78.7	62.4
Talc	80.0	63.5	30.5	33.4	0.0	0.0	0.0	0.0
Difference required for significance at 5%	--	9.5	-	19.6	-	13.4	-	15.4

Fungicidal and insecticidal dust combined, gave highly significant increase in emergence of seed exposed to insect attack. After six months storage, Spergon was significantly more effective than either Agrosan or Check (talc), as both the latter showed no emergence. Spergon DDT gave higher emergence figures than Agrosan BHC, but differences failed to reach significance.

Experiment 4: Pea

Twenty-five rice weevils and 25 bean weevils were added to each of the replicates. Seed stored for 12 months remained undamaged. Complete insect mortality was recorded after 12 months storage.

CONCLUSION

It can be concluded from the data presented above that BHC and DDT combined with fungicidal dusts give effective protection of French beans and maize against weevil infestation. Emergence figures indicated that with seeds stored for a period up to 12 months, there was no detrimental effect from a combination of dusts.

CONTROL OF ONION THRIPS

II. FINAL SELECTION OF INSECTICIDES

By H. Jacks and R. A. Harrison, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 8 June 1953*)

Summary

During the 1952-53 season tests were carried out with five insecticides which were previously found effective in control of *Thrips tabaci* Lind. These substances were used at various concentrations either singly or in combinations of non-residual and residual types.

Most effective control was obtained from applications of Trimort Wet. DDT at 5 lb. in 100 gal.

Introduction

In preliminary trials with a number of insecticides, Harrison and Jacks (1952) showed that parathion, HEPT plus lindane emulsion, HETP plus DDT emulsion, Isopestox, and DDT emulsion were most effective in controlling onion thrips (*Thrips tabaci* Lind.). Results of further investigations into efficacy of these and other insecticides are reported in this paper.

Onion thrips causes losses in onion crops throughout New Zealand and is particularly serious in the Franklin district. The type of damage caused is illustrated in Fig. 1.

Materials and Methods

The following insecticides were used:—

Folidol (25 per cent dimethyl-p-nitrophenyl thiophosphate), an emulsifiable preparation of parathion;

Isopestox (90 per cent bis-dimethylamino fluorophosphine oxide), a water miscible preparation;

Murphy's TEPP (40 per cent tetra-ethyl pyrophosphate), a water miscible preparation replacing Hexone (HETP, viz. 16 to 20 per cent TEPP) used previously (Harrison and Jacks, 1952);

Nexa (16 per cent lindane), an emulsifiable preparation.

Trimort Wettable DDT (20 per cent *p.p.i.*), an emulsifiable preparation, replaced Trimol DDT (25 per cent *p.p.i.*) used previously (Harrison and Jacks, 1952).

The non-residual TEPP was applied separately or in combination with the residual substances DDT, lindane or organic phosphorous compounds.

A field of onions (variety, Pukekohe Long Keeper) was divided into eight blocks. Each block was subdivided into 24 test plots, consisting of five adjacent rows of onions 5 yd. long. There were 24 treatments and each occurred once in each block. Treatments were randomized within each block.

FIG. 1.—Onion plant attacked by *Thrips tabaci*.
Photo: M. J. Dahlberg

Applications were made at ten days interval with Knapsack sprayers at the rate of 1.25 to 2.5 gal. of spray per treatment (200 linear yards of onions). The rate of application was lower during earlier stages of growth. Spraying was commenced on 24 September, 1952, when onion plants were approximately 6 in. high, and was continued until 14 January, 1953 (two weeks before harvest). All plots were sprayed with copper oxychloride (50 per cent copper) at 5 lb. in 100 gal. plus PEPS Spray adhesive (40 per cent polyethylene polysulphide latex) at .05 lb. in 100 gal. to prevent infection with onion mildew (*Perenospora destructor* (Berk) Coop.).

The thrip population was recorded on 17 December, 1952, 9 January, 1953, and 19 January, 1953. Ten adjacent plants in the centre of each plot were examined, thrips on the three innermost leaves being counted. The same plants were examined on each occasion.

RESULTS

Results are given in the Table. Since the number of thrips in the first count was distinctly lower than in subsequent counts, the first count was not used for evaluation of the efficacy of insecticides under test. Results of the last two counts are combined in Columns A and B and are used as a measure of the efficacy

RESULTS OF TRIALS WITH INSECTICIDES AGAINST THRIPS(TABACI) ON ONIONS DURING 1952-53 SEASON
(n = No. of thrips per treatment replicate)

No.	Treatment Name	Conc. per 100 gal. (lb.)	Mean log (n+1) for count of 17/12/52	Equivalent No. of thrips	Mean log (n+1) for count of 9/1/53 (A)	Equivalent No. of thrips	Mean log (n+1) for count of 19/1/53 (B)	Equivalent No. of thrips	A + B
1	Trimort Wet. DDT	5.0	.038	0	1.534	33	1.674	46	3.208
2	TEPP + Trimort Wet. DDT	0.75 + 3.0	.038	0	1.911	81	1.853	70	3.766
3	TEPP + Nexa	0.75 + 3.0	.188	1	1.671	73	2.028	106	3.899
4	TEPP + Trimort Wet. DDT	0.75 + 1.25	.135	0	2.124	132	1.939	86	4.063
5	TEPP + Trimort Wet. DDT	0.38 + 2.5	.075	0	2.127	133	1.947	87	4.074
6	Trimort Wet. DDT	1.25	.113	0	2.140	137	1.974	93	4.114
7	TEPP + Trimort Wet. DDT	1.5 + 2.5	.256	1	2.167	146	1.958	90	4.125
8	Polidol	2.0	.087	0	2.112	128	2.035	107	4.147
9	TEPP + Nexa	0.38 + 1.5	.417	2	2.156	142	2.018	106	4.174
10	Nexa	3.0	.232	1	2.168	146	2.117	130	4.285
11	Polidol	0.5	.345	1	2.219	165	2.144	138	4.363
12	TEPP + Isopestox	1.5 + 1.0	.254	1	2.292	195	2.096	124	4.388
13	TEPP + Nexa	1.5 + 1.5	.147	0	2.218	164	2.192	155	4.410
14	TEPP + Nexa	0.75 + 0.75	.113	0	2.330	213	2.148	140	4.478
15	TEPP	1.5	.232	1	2.420	262	2.116	130	4.536
16	TEPP	0.38	.451	2	2.469	293	2.133	135	4.602
17	TEPP + Isopestox	0.75 + 0.5	.282	1	2.466	292	2.186	153	4.652
18	Isopestox	0.5	.675	4	2.574	374	2.103	125	4.677
19	TEPP + Isopestox	0.38 + 1.0	.547	3	2.492	309	2.194	155	4.686
20	Isopestox	2.0	.749	5	2.511	323	2.211	162	4.722
21	Nexa	0.75	.742	5	2.542	347	2.188	153	4.730
22	TEPP + Isopestox	0.75 + 2.0	.395	1	2.607	404	2.192	165	4.799
23	Control	-	1.061	11	2.723	528	2.361	229	5.084
24	Control	-	1.143	13	2.825	667	2.342	219	5.167
Difference required for significance at 5% level			.327		.165		.137		.215
Difference required for significance at 1% level			.432		.218		.181		.283

of a treatment. Treatments are listed in order of efficacy in the Table.

Trimort Wettable DDT applied at 5 lb. in 100 gal. water was significally more effective than all other treatments.

TEPP plus Trimort Wettable DDT at 0.75 lb. and 5 lb. in 100 gal. respectively, although not significantly different from TEPP plus Nexa emulsion at 0.75 lb. and 3 lb. respectively, gave significantly better control than the remaining treatments.

DISCUSSION

The thrip population was slight over the whole experimental area until late December, 1952. It appears that cold and wet weather conditions discouraged development of thrip population since numbers increased considerably with the advent of fair and warm weather from end of December until completion of the trial.

Higher concentrations were more effective than lower strengths. Further increase in strengths of sprays made up with DDT, lindane or parathion emulsions may increase the measure of control, but the appearance of plots sprayed with DDT emulsion did not suggest any need for improvement of results. As it was found that adequate control of onion thrips can be obtained with DDT or lindane emulsions, at comparable strengths, it becomes unnecessary to use more dangerous substances.

From observations over several seasons in the Franklin district it appears that the thrips populations begin to build up towards the end of November or middle of December. Spraying for control of onion thrips should therefore commence in early November.

RECOMMENDATIONS

Effective control of onion thrips may be obtained by applications of DDT emulsion at the rate of 1 lb. *p.p.i.* per 100 gal. made at intervals of ten days from early November until 14 days before harvest.

ACKNOWLEDGMENTS

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Statistical analysis of results was carried out by Mr. W. B. Taylor, Applied Mathematics Laboratory, Department of Scientific and Industrial Research.

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BOOK REVIEW

THE COMPARATIVE BIOCHEMISTRY OF THE CAROTENOID PIGMENTS

By T. W. Goodwin. Chapman & Hall, London.

In any highly specialised field of active research there is an obvious reluctance on the part of most workers to produce a text-book which must of necessity be out of date almost immediately. Nevertheless a period of consolidation is sooner or later reached when a suitable text will serve a most useful purpose. Such a stage has been reached in the carotenoid pigment field and such a demand has been admirably met by the above book. Written with the meticulous accuracy and attention to detail so characteristic of the Liverpool team, the book will be equally useful both to the general reader and to the specialist, whether his approach be biochemical or along more biological lines.

No comprehensive survey of the carotenoids has appeared since the early 1930s and Goodwin, while re-examining work prior to this time, has adequately reviewed and discussed all important contributions since that date. It is indeed a tribute to the author and publishers that it has been possible to include all work published up to almost the end of 1951.

While it is not the aim of the book to cover carotenoid chemistry, an introductory chapter provides sufficient chemistry and nomenclature to keep the work self-contained. Part I then deals with the carotenoids in plants—their formation and the environmental factors which influence it, and theories for their functions in higher and lower forms of plant life. The second part covers animal carotenoids, dealing with their absorption, occurrence, metabolism and possible functions in a wide range of animal species. Each chapter includes an extremely comprehensive and useful set of references to original work. There are also appendix tables giving the carotene content of a wide range of plants.

It is clearly the author's aim to establish the importance of the carotenoid pigment as such, and not, as they have so often been regarded in the past, merely "vitamin A precursors." Only one short chapter is devoted to the conversion of carotenoids to vitamin A. Despite the volume of work carried out recently in this field, this treatment probably represents its relative importance in relation to carotenoid biochemistry. That many of the carotenoids have other clearly defined functions, probably just as important as their pro-vitamin A activity, is well established. Our knowledge of their functions is most limited. A number of Goodwin's suggestions of possible modes of action, particularly their relationship with reproductive processes should stimulate further research.

W.A.McG.

PLANT QUARANTINE

I. LIST OF PLANT DISEASES AND PESTS INTERCEPTED IN NEW ZEALAND IN 1951

By H. Jacks, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 17 June 1953*)

Introduction

Plants and plant products introduced into New Zealand frequently carry plant pathogens or insect pests. In the present list are recorded the plant diseases and pests intercepted in 1951. Similar lists will be prepared for subsequent years. Specimens were submitted by Horticultural Inspectors of the Department of Agriculture and identified by specialist officers of the Plant Diseases Division. Specimens submitted but found to carry organisms which could not be identified for various reasons (damage, failure in culture, or rearing tests, etc.) are not listed. Diseases and pests not recorded in New Zealand are marked with an asterisk.

LIST OF PLANT DISEASES AND PESTS INTERCEPTED IN NEW ZEALAND IN 1951

Disease or Pest		No. of Con-signments	Host		Country of Origin	Discovered in:
Common Name	Generic Name		Common Name	Generic Name		
Diseases:						
Leaf-spot	*Ascochyta* spp.	1	Kurrajong	*Sterculia diversifolia*	Australia	Auckland
Rot	*Glomerella cingulata* (Stonemn.) Spauld & V. Schr.	1	Orange, sweet	*Citrus sinensis* Osb.	"	"
Verrucosis	*Elsinoe faweetti* Britane & Jenkins.	1	Grapefruit	*Citrus maxima* Men. & Lee.	Samoa	"
Pests:						
Ants	*Pheidole megacephala* Fab.	1	Coconut palm	*Cocos nucifera* L.	Australia	"
Aphids	*Cerataphis lataniae* Boisd.*	2	Orchids	*Orchidaceae*	"	"
Beetles	*Carabidae*	1	Soil	—	Tasmania	Christchurch
"	*Lasioderma serricorne* F.	1	Ginger	*Zingiber officinale* Rosc.	Jamaica	Dunedin
	Cleridae sp.	1	"	" " "	"	"
"	*Ptinus tectus* Boield	1	"	" " "	"	"
"	*Dermestes maculatus* Deg.	1	Cashew nuts	*Anacardium occidentale* L.	India	"
"	*Necrobia rufipes* Deg.	1	" "	" "	"	"
Bulb Mite	*Rhizoglyphus echinopus* F. & R.	1	Hyacinths	*Hyacinthus* L.	Holland	Christchurch
" "	" "	1	Tulips	*Tulipa* L.	"	"
" "	" "	1	Iris	Iris L.	"	"
Capsid bug	*Capsidae* sp.	1	Cuttings	—	Australia	"
Cockroach	*Periplaneta australasiae* F.	1	Timber	—	China	Dunedin
Flies	*Stratiomyiidae* sp.	1	Cuttings	—	Australia	Christchurch
"	*Scatopsidae* sp.	1	Ginger	*Zingiber officinale* Rosc.	Jamaica	Dunedin

Lace-bug	*Campylostira verna* Fall.*	1	Rose	*Rosa* spp.	England	Auckland
Mealy-bug	*Pseudococcus brevipes* Ckll.	1	Pineapple	*Ananas comosus* Merr.	Australia	Wellington
Scales	*Lecaniinae* sp.	1	Camellia	*Camellia reticulata* Lindl.	Holland	Palmerston North
,,	,,	1	,,	*Camellia* sp.	Australia	Auckland
,,	,,	1	Litchi	*Litchi* sp.	,,	,,
,,	,,	1	,,	,,	,,	Dunedin
,,	,,	1	Pecan	*Carya illinoensis* Koch.	,,	Auckland
,,	*Parlatoria zizyphus* (Lucas)*	1	Lime	*Citrus aurantifolia* Swingle	Indonesia	,,
,,	*Hemiberlesia lataniae* Sign.*	1	Avocado	*Persea Americana* Mill.	Australia	,,
,,	,, ,, *	1	Coconut palm	*Cocus nucifera* L.	,,	,,
,,	*Chrysomphalus dictyospermi* Morg.*	1	,, ,,	,, ,,	,,	,,
,,	*Coccus hesperidum* L.	1	Daphne	*Daphne* spp.	,,	Christchurch
,,	,, ,,	1	Leea	*Leea amabilis*	Tonga	Auckland
,,	*Lepidosaphes machili* (Mask)*	1	Orchids	*Orchidaceae*	Australia	,,
,,	*Aonidiella aurantii* Mask.	1	Orange, sweet	*Citrus A. sinensis* Osb.	,,	,,
,,	*Aulacaspis* sp.	1	Frangipani	*Plumeria* spp.	Fiji	,,
Mealy-bug	*Eriococcus* sp.	1	Grapefruit	*Citrus maxima* Men. & Lee	Samoa	,,
,,	,,	1	Queensland nut	*Macadamia ternifolia*, F. Muell.	Australia	Dunedin
Scales	*Lepidosaphes beckii* Newm.*	1	Orange, sweet	*Citrus sinensis* Osb.	Raratonga	Auckland
,,	*Diaspidinae* sp.	1	Leea	*Leea amabilis*	Tonga	,,
Thrips	*Heliothrips haemorrhoidalis* Bch.	1	Grape fruit	*Citrus maxima* Men. & Lee	Samoa	,,
Weevil	*Bruchus chinensis* L.*	1	Beans	*Phaseolus* spp.	China	Dunedin
,,	*Zabrotes sub-fasciatus* (Bch.)	1	,,	,,	Abyssinia	Auckland
,,	*Hypera nigrirostis* F.*	1	Rose	*Rosa* spp.	England	,,
,,	*Euscepes postfasciatus* Fairm.*	1	Kumara	*Ipomoea* spp.	Raratonga	,,
,,	,, ,,	1	,,	,,	Mangaia	,,
,,	*Bruchus rufimanus* Boh.	2	Beans	*Phaseolus* spp.	Burma	Wellington

HOST PLANTS OF *LITHOCOLLETIS MESSANIELLA*

By K. A. J. Wise, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 30 June* 1953)

Summary

Leaf-mining larvae of *Lithocolletis messaniella* Zell. have a restricted host-plant range in countries where they are normally found. In New Zealand, after a recent introduction, this species has extended its range considerably. The host-plant list now contains 10 species in addition to *Quercus* spp. New records are species of *Fagus, Nothofagus, Betula, Parrotia, Liquidambar, Carya* and *Feijoa.*

Introduction

In discussing the Oak leaf-miner *Lithocolletis messaniella* Zeller, Jacobs (1945) recorded as hosts, all species of *Quercus* (Oaks) and also *Castanea sativa* Will. (Sweet Chestnut) and *Carpinus betulus* L. (Hornbeam).

In 1950, *L. messaniella* was discovered for the first time in New Zealand. In the Hastings district this leaf-miner has since become a pest of some importance, the type of damage caused being illustrated in Plate 1. All species of Oak inspected and also many other shade trees have been found to be infested. It is of particular interest that infestation has spread to a native Beech and nursery stocks of Feijoas.

Host Plants of *Lithocolletis messaniella* Zeller

Moths have been bred out and identified from the plant species marked * in the list set out below. Other species are recorded from the presence of typical mines.

Fam. Fagaceae

Quercus spp.

All *Quercus* spp. inspected were infested. Some species infested are not listed as verification of specific names is not obtainable. There are further species in New Zealand which have not been examined. Identified species are:—

**Quercus robur* L.	Common or English Oak.
**Quercus ilex* L.	Holm or Holly Oak (Evergreen).
**Quercus borealis* Michx.	Red Oak
**Quercus palustris* Muenchh.	Pin Oak
**Quercus coccinea* Muenchh.	Scarlet Oak
**Fagus sylvatica* L.	European Beech
Fagus sylvatica L. var. *heterophylla* Loud	Fernleaf or Cutleaf Beech
**Fagus sylvatica* L. var. *purpurea* Ait.	Copper Beech
Nothofagus fusca Oerst.	Red Beech
Nothofagus procera Oerst.	
**Castanea sativa* Will.	Sweet Chestnut

Fam. Betulaceae

**Betula verrucosa* Ehrh.	Silver Birch

Fam. Corylaceae

**Carpinus betulus* L.	Hornbeam

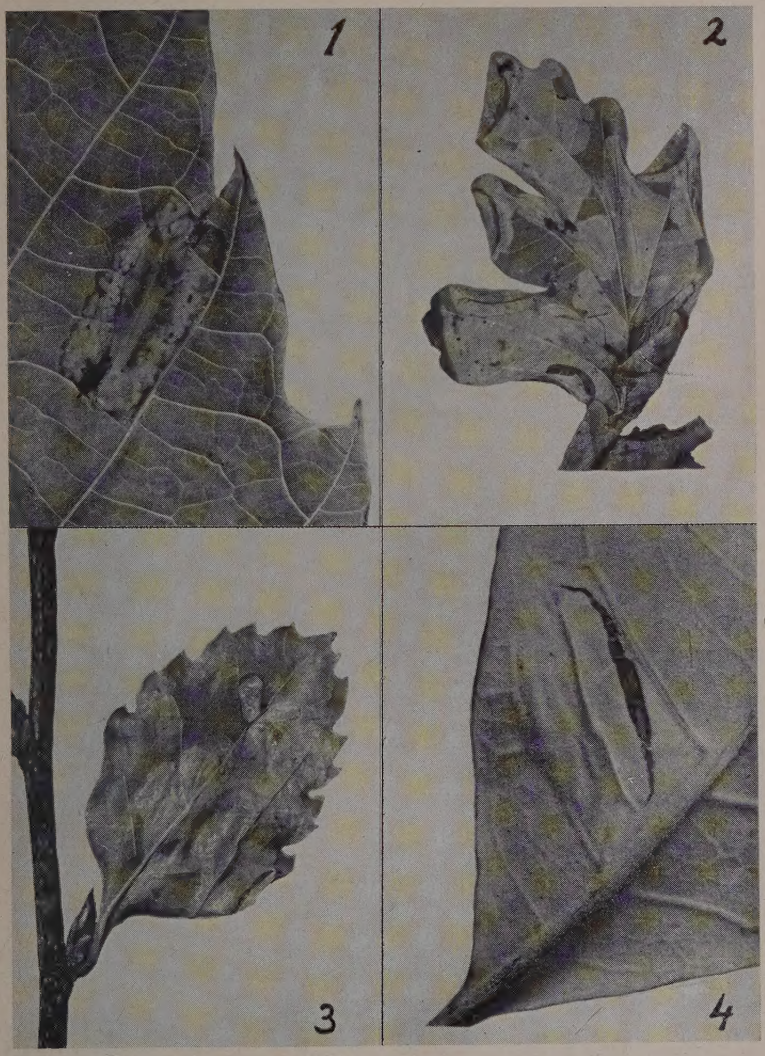

PLATE 1.—Leaf-mines of *Lithocolletis messaniella* Zeller.

FIG. 1.—Typical mine in Chestnut (*Castanea sativa* Will.). (x 2½) *Photo: J. W. Endt.*

FIG. 2.—Severe infestation in English Oak (*Quercus robur* L.). (x 1⅓) *Photo: S. A. Rumsey*

FIG. 3.—Leaf of Red Beech (*Nothofagus fusca* Oerst.) showing mature mine almost completely occupying one side of the leaf. (x 1⅙) *Photo: J. W. Endt.*

FIG. 4.—Mine in Feijoa (*F. sellowiana* Berg.). (x 2¾) *Photo: J. W. Endt.*

Fam. Hammamelidaceae	
Parrotia persica C. A. Mey	Ironwood
Liquidambar styraciflua L.	Liquidambar
Fam. Juglandaceae	
Carya pecan Engler and Graeh.	Pecan
Fam. Myrtaceae	
**Feijoa sellowiana* Berg.	

ACKNOWLEDGEMENT

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CORRIGENDUM

N.Z. J. Sci. Tech. A35 : 58-62.

Influence of α-Naphthaleneacetic acid on Pre-harvest Drop of Jonathan Apples.

Transpose graphs on pages 60 and 61. Figure numbers and captions remain as set on present pages.

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